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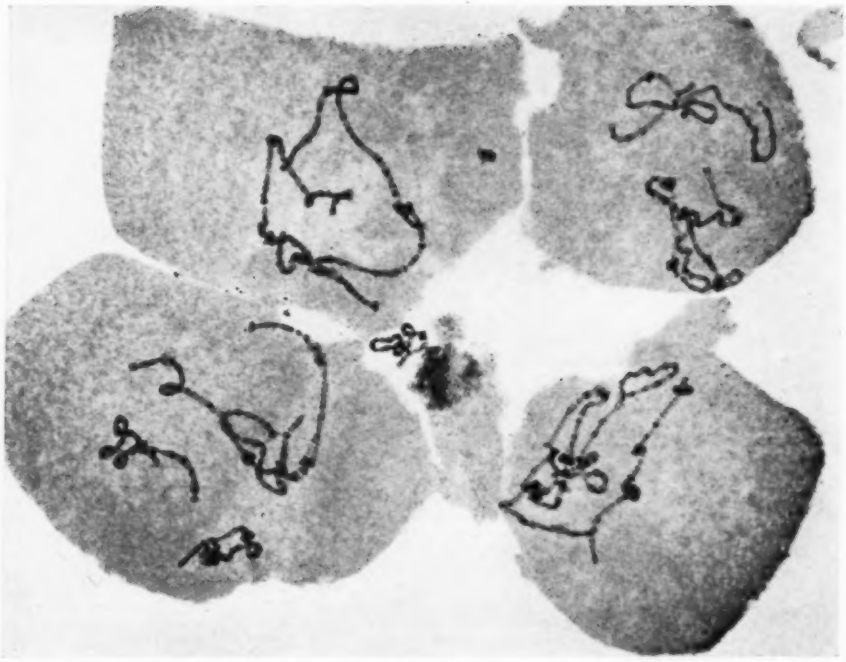

SALIVARY GLAND CHROMOSOMES AS SEEN IN THE CELLS

(SEE PAGE 177)

Russian Research in Human Genetics

Two "Permanent Wave" Genes in Mice

Eight Generations of Inbred Pigs

A Multiple Mosaic in Maize

VOLUME 26 MAY, 1935 NUMBER 5

The American Genetic Association

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CONTENTS

STRUCTURE OF THE SALIVARY GLAND CHROMOSOMES IN SCIARA
By C. W. Metz 177

A SECOND REXOID COAT CHARACTER IN THE HOUSE MOUSE
By Clyde E. Keeler 189

HUMAN GENETICS IN RUSSIA
A Review by H. J. Muller 193

EUGENICS AND RURAL TRENDS
A Review by O. F. Cook 201

AN EIGHT GENERATION EXPERIMENT IN INBREEDING SWINE
By R. E. Hodgson 209

THE ROBERTSON STRAIN OF THE WASHINGTON NAVEL ORANGE
By A. D. Shamel and C. S. Pomeroy 213

Brief Reviews and Notes

ANENCEPHALY IN TWINS 188
A MULTIPLE MOSAIC IN MAIZE 191
CORRECTION OF TWO ERRORS REGARDING SELECTIVE FERTILIZATION 192
RESEMBLANCES OF ANTHROPOIDS AND MEN 196
COMPARATIVE PSYCHOLOGY OF MAMMALS 198
CANINE PSYCHOLOGY 199
STATISTICS OF VARIABILITY 200
COMFORT FOR PARENTS 205
HEREDITY IN THE VERY YOUNG 205
MAN IN PREHISTORY 206
HISTORY OF THE BACKBONE 207
NEMATODES AND PLANT DISEASE 222

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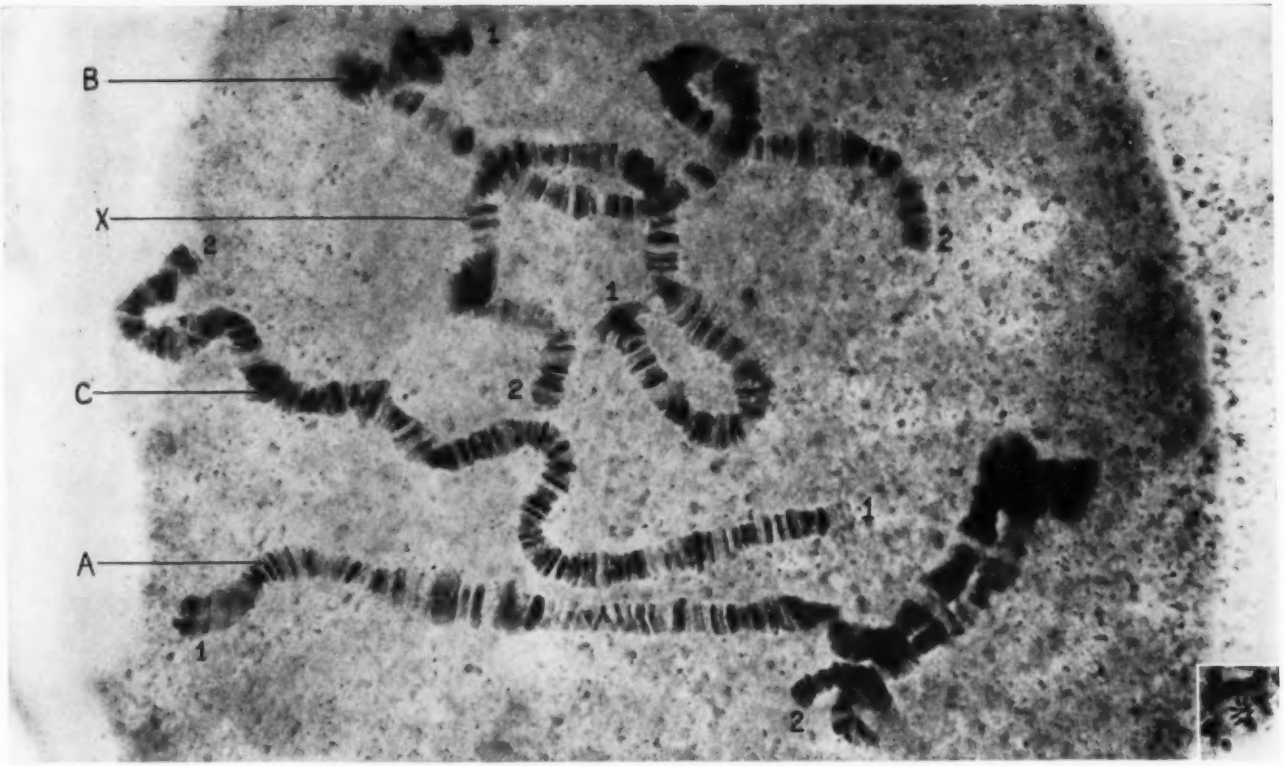


SALIVARY CHROMOSOMES COMPARED WITH "NORMAL"

Frontispiece

The main figure shows the entire chromosome group of a salivary gland cell of *Sciara ocellaris*, showing the four chromosomes, each representing a pair of homologues fused together. One is about twice as long as the others. It represents the V-shaped pair seen in other cells. The other three are rod-like in ordinary somatic figures (see lower right). From an iron-aceto-carmine smear. The insert at the right shows the ordinary somatic chromosome group of a female *Sciara coprophila*, from an embryonic (ganglion?) cell. The corresponding group of *S. ocellaris* is practically indistinguishable from this. Each includes one pair of V-shaped and three pairs of rod-like chromosomes. The magnification of these two photographs is approximately the same (750×), so that the actual difference in size of the chromosomes is fairly accurately represented in the figure.

STRUCTURE OF THE SALIVARY GLAND CHROMOSOMES IN SCIARA

C. W. METZ

Dept. of Embryology, Carnegie Institution of Washington, Baltimore, Md.

SINCE the salivary gland chromosomes of *Sciara* are particularly favorable for study of chromosome organization we are glad to accept the Editor's invitation to present here some results of recent studies on them. The observations represent results of cooperative studies in this laboratory by Miss E. H. Gay, Dr. William L. Doyle and the writer. For the most part they have been recorded briefly in earlier papers[3, 13, 14].

The object of our work on *Sciara* has been somewhat different from that of Painter and others on *Drosophila*. We have been more concerned with an attempt to get at the finer details of chromosome structure, and less with locating or identifying any particular genes. For this reason the present account will supplement that of Painter[15] recently presented in this Journal.*

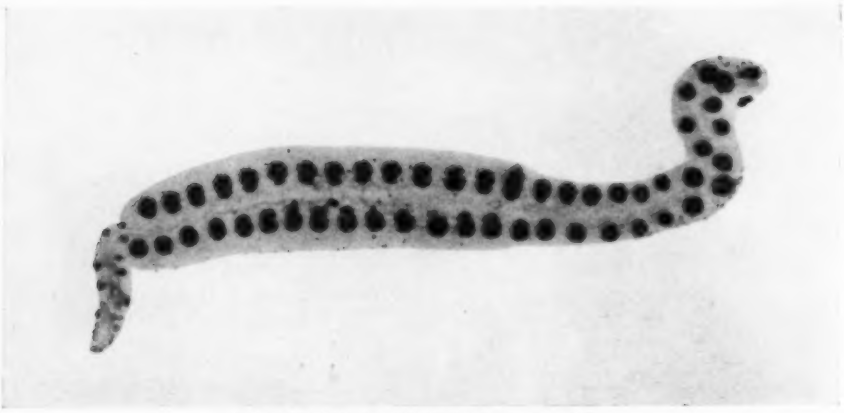
Since the work of other investigators has been considered by Painter it will not be discussed here. The main purpose of this paper is to show photographically the general type of organization found in the giant salivary chromosomes in *Sciara*, and to indicate something of the constancy of the structures as well as the degree of variation found in different preparations. Photographs of selected regions in individual chromosomes, taken from different preparations, will be compared, and the effects of different modes of fixation, etc., will be noted for the purpose of ascertaining the nature and constancy of the organization. Although certain interpretations as to chromosome organization and its relation to genes will be mentioned, detailed consideration of such problems will be left for a later paper.

Before describing the salivary gland chromosomes it seems desirable to refer briefly to certain questions which are frequently asked concerning them. A correct understanding of the features included in this category is essential to any interpretation of the structures themselves. For the sake of simplicity the points will be presented in the form of question and answer.

1. Do these cells and chromosomes divide? No, they do not divide and have not divided for a comparatively long period of time. The salivary gland is formed in the embryo before it escapes from the egg, and thereafter no mitosis is known to occur. The gland is a larval structure and will degenerate at a stage following shortly after that at which the chromosomes reach their maximum size and are best studied. Although it seems clear that the chromosomes at the stage represented in the present paper are not actually degenerating, in the ordinary sense of the term, it is uncertain as to how much structural change they may have undergone during the long period of growth and specialization which has elapsed since the last mitosis occurred.

2. What stage in the ordinary cell cycle is represented in these cells? Or, in other words, are these chromosomes comparable to metaphase, prophase or "resting stage" chromosomes in other cells? In the writer's opinion they represent attenuated resting stage chromosomes rather than condensed prophase or metaphase chromosomes. As Heitz and Bauer, Painter and others[2, 6, 7] have

*It will likewise supplement that of Bridges which appeared after the present paper went to press. In this connection it should be noted that the term "segment" is used very differently in these papers. In the present account it is used mainly in a descriptive sense like the term "band" and may be applied to structures which are actually composed of two or more segments close together.



THE ENTIRE SALIVARY GLAND

Figure 1

Entire salivary gland of *Sciara coprophila* Lint., except the narrow apical part. From preparation by Dr. W. L. Doyle, stained with the Feulgen technique, which colors only the chromosomes. The gland of *S. ocellaris* is essentially the same as this in structure. The gland proper consists of only two rows of cells, one on each side of the duct, making a flat structure ideal for cytological study. The chromosomes used for study are in the large nuclei in the broad part of the gland, which usually consists of about 30 cells (at left in photograph). In the normal condition the chromosomes are coiled about in the form of a spireme within the nucleus. For detailed study the nuclei are broken and the chromosomes spread out, as shown in the other photographs.

pointed out, each one represents a *pair* of homologous chromosomes, in intimate side by side union. This is in accord with expectation, since in the Diptera the chromosomes ordinarily undergo somatic synapsis and associate side by side in most, if not all, tissues[9, 10, 17]. Our evidence would indicate that the union of homologues takes place at an early stage in the life of the cell, rather than late as stated by Painter.

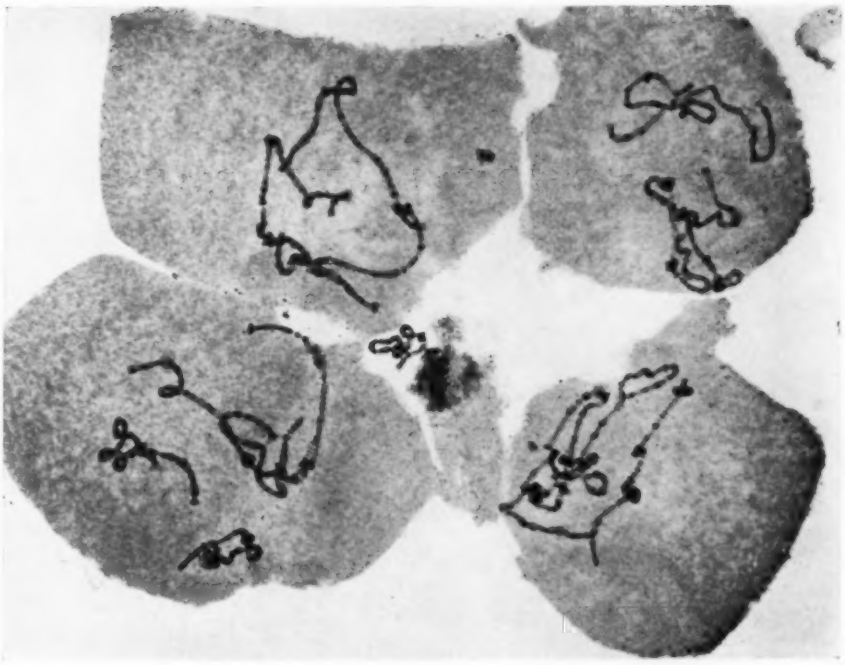
Explanation of Photographs

The photographs shown in this paper were made by Mr. Chester Reather and Mr. O. O. Heard, of this laboratory. Mr. Reather, with the writer's assistance, made all except that shown in the Frontispiece, which was made by Mr. Heard. All Figures except 1 and the insert in the Frontispiece are from preparations made by Miss E. H. Gay. With the exception of those taken at low magnification, the photographs were mostly made with an apochromatic 2 mm. objective, of 1.4 n.a., on panchromatic "Wratten-M" plates, with the aid of a green filter (used because of the red stain). Most of them were made at an initial magnification of 1300 or 1600 diameters. Actual magnifications of the figures are given in the legends.

Except where otherwise noted all figures are from *Sciara ocellaris* Comst. The others are from *S. coprophila* Lint., which has a somatic chromosome group of the same general type as that of *ocellaris*. All are from female larvae. In most cases the chromosomes are flattened somewhat by pressure of the coverslip in making the smear, so they appear broader than they actually are.

Structure of the Salivary Gland

The salivary gland of *Sciara* could hardly be designed better than it is for purposes of chromosome study. As shown in the accompanying photograph (Figure 1) it is a flat structure consisting of two rows of cells, separated by a duct. The gland proper contains a small and fairly constant number of relatively enormous cells. In the species



SALIVARY CHROMOSOMES IN THE CELLS
Figure 2

Four salivary gland cells of *S. ocellaris* from an iron-aceto-carmine smear. Photographed at low magnification to show general appearance of the cells and chromosomes in such preparations. One chromosome has been pushed out of the upper cell at left and lies near center of the field. In all such preparations the nuclei are broken and the cells are greatly flattened. (200×)

on which the present study is mainly based (*S. ocellaris*, Comst.) these cells flatten out readily in aceto-carmine preparations, permitting ready separation and spreading of the chromosomes as shown in the Frontispiece.

The Chromosome Group

The entire chromosome group of a salivary gland cell is shown in the Frontispiece, together with the corresponding group from a large "ordinary" somatic cell, shown for comparison. There are four pairs of chromosomes, one long and V-shaped (in ordinary mitoses) and three rod-like. In male somatic cells the *X* chromosome is unpaired.* No *Y* chromosome is present.

For the sake of convenience the chromosomes are designated by letters, and the two ends of each are numbered, as shown in the Frontispiece. The long autosome is designated *A*, the two smaller autosomes *B* and *C* and the sex chromosome *X*. Fortunately very little nucleolar or "chromocenter" material is present in the nucleus; hence the chromosomes in good preparations lie free and are easily studied, as shown in the Frontispiece and in Figure 2.

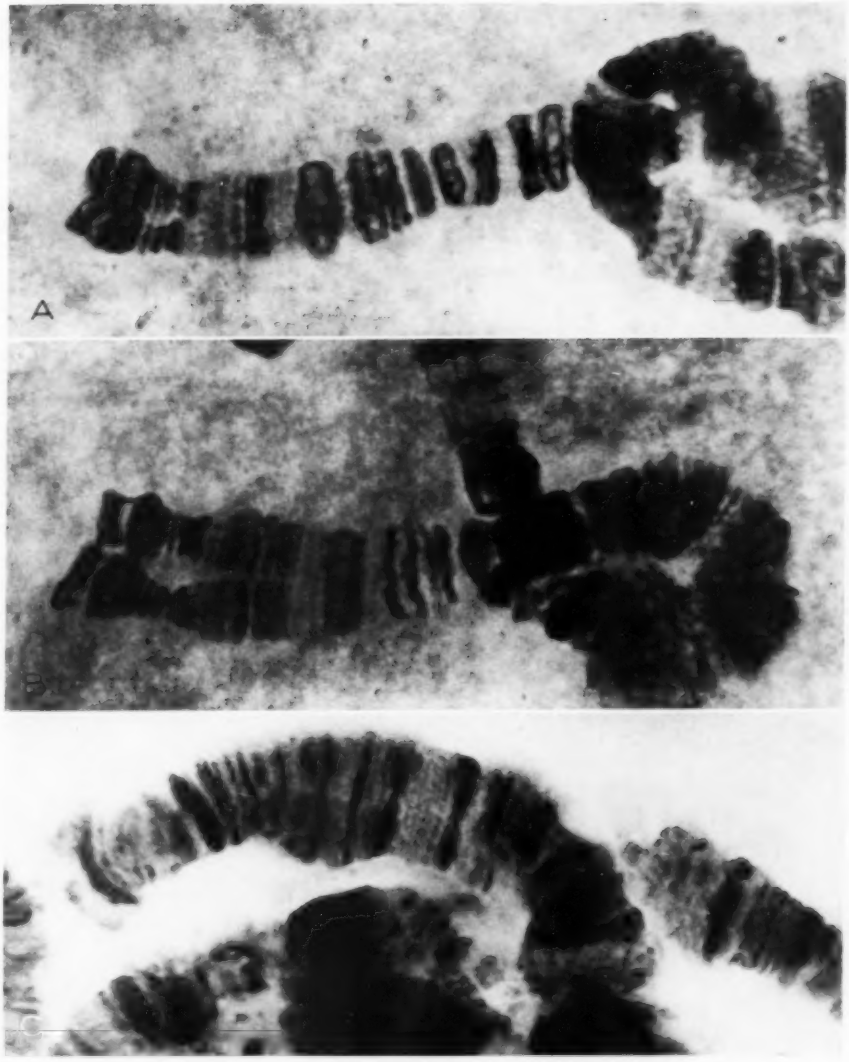
Each chromosome has its own structural characteristics, and may readily be identified. One end of the long chromosome (pair) is represented in Fig-

* Its mate is eliminated from somatic cells during cleavage in the egg. See Metz[12], DuBois[4,5], Schmuck[16].

EACH CHROMOSOME HAS CHARACTERISTIC "LANDMARKS"

Figure 3

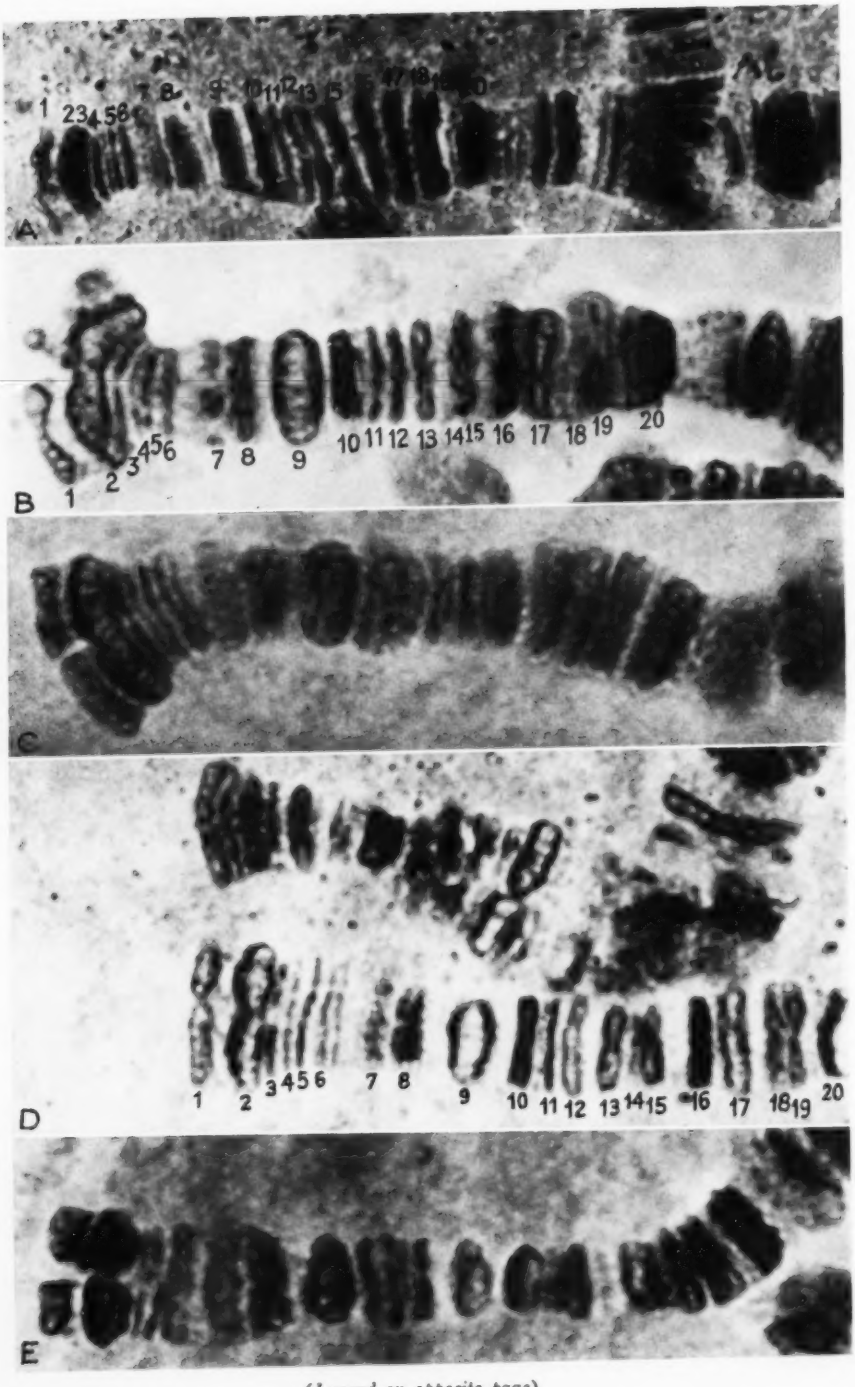
Chromosome *C* of *S. ocellaris*, entire, from an iron-aceto-carmine preparation. One end of this chromosome is commonly spread out, more or less fan-like, as shown here. The other end is blunt and there is usually a constriction near the tip. Each end has its own characteristic series of chromatic segments. (1200×)



CONSTANCY OF SEGMENTAL STRUCTURE

Figure 4

All three illustrations show different preparations of the same chromosome, the "left end" or "End *1*" of the long chromosome, of *S. ocellaris* (designated *chromosome A*). This end of this chromosome is often double, revealing the two separate chromosomes which have not fused intimately here. *A* and *B* are from an iron-aceto-carmine smear, prepared in such a way as to make many of the chromatic segments relatively thick and bladder-like. *C* is from a preparation treated with osmic acid solution and formalin, followed by iron-aceto-carmine. This treatment results in less shrinkage and distortion of chromosomes, although in this particular case the chromosomes have suffered somewhat from being forced entirely out of the cell, where they lie free from the cytoplasm. Note the finely granular appearance of the segments and the presence of what appear to be very thin and delicate segments between the more prominent ones. Compare with Figure 5, which represents a series of photographs of this same end of chromosome *A*, taken from different cells and different preparations to show that in spite of variations in details of structure the segmental organization is constant. (End *1*, of chromosome *C*, lies at the right of chromosome *A*, in Figure 4*C*.) (2200×)



(Legend on opposite page)

ures 4-5. This is chromosome *"A"*. The end just referred to is designated as number *1*, and the other end, shown in Figure 6, as number *2*. Present attention will be confined mainly to the end regions of the different chromosomes, although the structures are just as characteristic in other regions.

In Frontispiece the general characteristics of each chromosome are shown fairly well. Since this figure is not highly magnified the details may be seen better, perhaps, with the aid of a reading glass or other magnifier. Such an examination, together with a comparison with the photographs taken at higher magnification, will serve to distinguish readily the individual chromosomes. Figure 2 gives a good idea of the structures as seen under low powers of the microscope.

Chromosome *C* is represented in its entirety in Figure 3. One end of this chromosome commonly spreads out, fan-like, and is granular or speckled in fixed preparations. In other cases, however, it is not expanded, and the fan-like region apparently contains definite segments like the other regions. The significance of this will be discussed elsewhere. The other end of this chromosome is blunt, and contains certain segments of special interest which will likewise be considered elsewhere.

Equally characteristic features distinguish chromosome *B* and the *X* chromosome. Some of these will be noted below. In males the *X* differs markedly in staining capacity and appearance from the autosomes, but does not appear to be distinctly smaller than *B* and *C* as would be expected from the fact that it is a single chromosome instead of a pair. In both sexes one end of this chromosome is commonly swollen into a large vesiculated body of unknown significance. This is shown in Figure *7A*, from a rare case in which this body is fused to a segment some distance from the end in the same chromosome. In side view the end body is often hatchet-like in appearance, as in the Frontispiece.

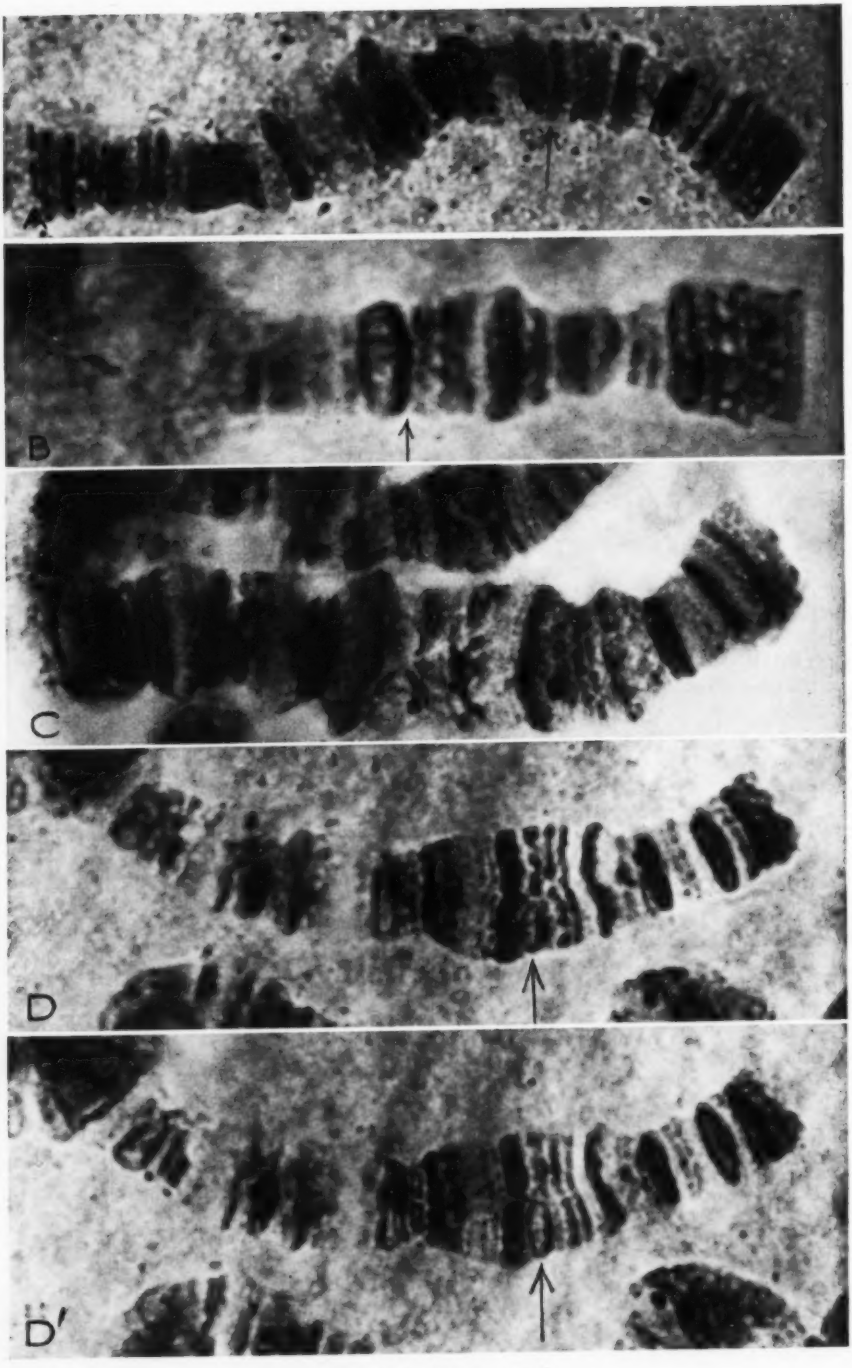
Since especial interest attaches to the *X* chromosome in *Sciara*, because of the remarkable mode of reproduction and sex determination here, and the fact that two or more kinds of *X* chromosomes are found in this material[12], the structure of this chromosome will be treated in a separate paper.

STRUCTURE OF CHROMOSOME *A*
Figure 5

In this figure five views of end *1* of chromosome *A* are shown for comparison. This is the same region as that shown in Figure 4. *A* and *B* were both prepared by the iron-aceto-carmine method, but *A* was exposed longer to Ringer's solution before fixation. As a result the chromatic segments are mostly narrower and more dense and do not appear to be filled with vacuoles as do many of those in *B*. Corresponding segments or regions are given corresponding numbers in these two figures (and in D), in order to facilitate comparison. The same series may be identified in Figure 4. No attempt is made to number all segments here, and the numbers do not necessarily designate single segments. Some of the "bands" are obviously compound. The photographs shown in *C*, *D*, and *E* are from iron-aceto-carmine preparations, not exposed long to Ringer's solution. *C* and *E* are from the same preparation. In *D* both ends of the chromosome are shown (compare with Figure 6, which shows other views of end *2* of this chromosome). *A*, 1900×; *B*, 2800×; *C-E*, 2900×.

Constancy of Chromosome Organization

The best test of constancy of organization in chromosomes comes through comparative study of the structures in material prepared in different ways. For this reason we have made a comparative study of our preparations. A brief summary of the evidence, together with suggestions as to the interpretations it seems to require, may be presented at this time. The aim of such work, of course, is to determine what conditions exist in the living chromosome. Since the details of chromosome structure cannot be observed in the normal living condition here, interpretations must be based on observation of treated material, either living or killed. Such interpretations must be made with caution, and most of those presented here are regarded as tentative.



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Our observations agree with those of earlier workers, on *Chironomus, Drosophila,* etc.[6, 7, 15], in indicating that each chromosome in the salivary gland possesses a relatively constant architecture consisting of alternate chromatic and achromatic segments of various sizes, arranged in linear order. The chromatic ones are the "bands," "discs," "rings," etc., of earlier authors. With different methods of treatment these segments give different details of appearance, but it seems clear that they are present as organized structures in the living chromosome, even though invisible in the truly normal, living chromosome (see Doyle and Metz[3]). The constancy of the segmental structure as regards gross features, and its variability as regards structural details, is indicated to some extent by Figures 4, 5 and 6. These two series of photographs represent, respectively, ends 1 and 2 of chromosome *A*, as seen in different cells and in different preparations. The technique employed in making the preparations is explained in the legends.

In comparing the effects of different modes of treatment on the same structures it is seen that the most conspicuous modifications are those involving the chromatic segments. With proper treatment these segments may appear mainly in the form of thin, sharply outlined discs; while with other methods they may appear granular, or swollen, or may combine to form thick, heavy segments or bladder-like structures. In many cases some segments appear in the form of zig-zag bands. These various modifications of form seem to have special significance in connection with the problem of interpreting the organization in terms of genes.

It should be emphasized that any such interpretation should take into account the fact that upon fixation in the usual manner these chromosomes appear to shrink fully fifty per cent in volume and to undergo marked distortion as regards structural details (Doyle and Metz[3]).

Our observations suggest strongly that fundamentally each chromatic segment is a thin, smooth disc, and that the granules, zig-zag structures, etc., are modifications due to the treatment employed. This is suggested particularly by the fact that one given segment may in different preparations exhibit different types of structures, and that the treatment resulting in smooth discs appears to give less distortion of the chromosome than any of the others. The writer has made a careful study of one particular series of segments, using various techniques, for this purpose. The results will be presented more in detail later.

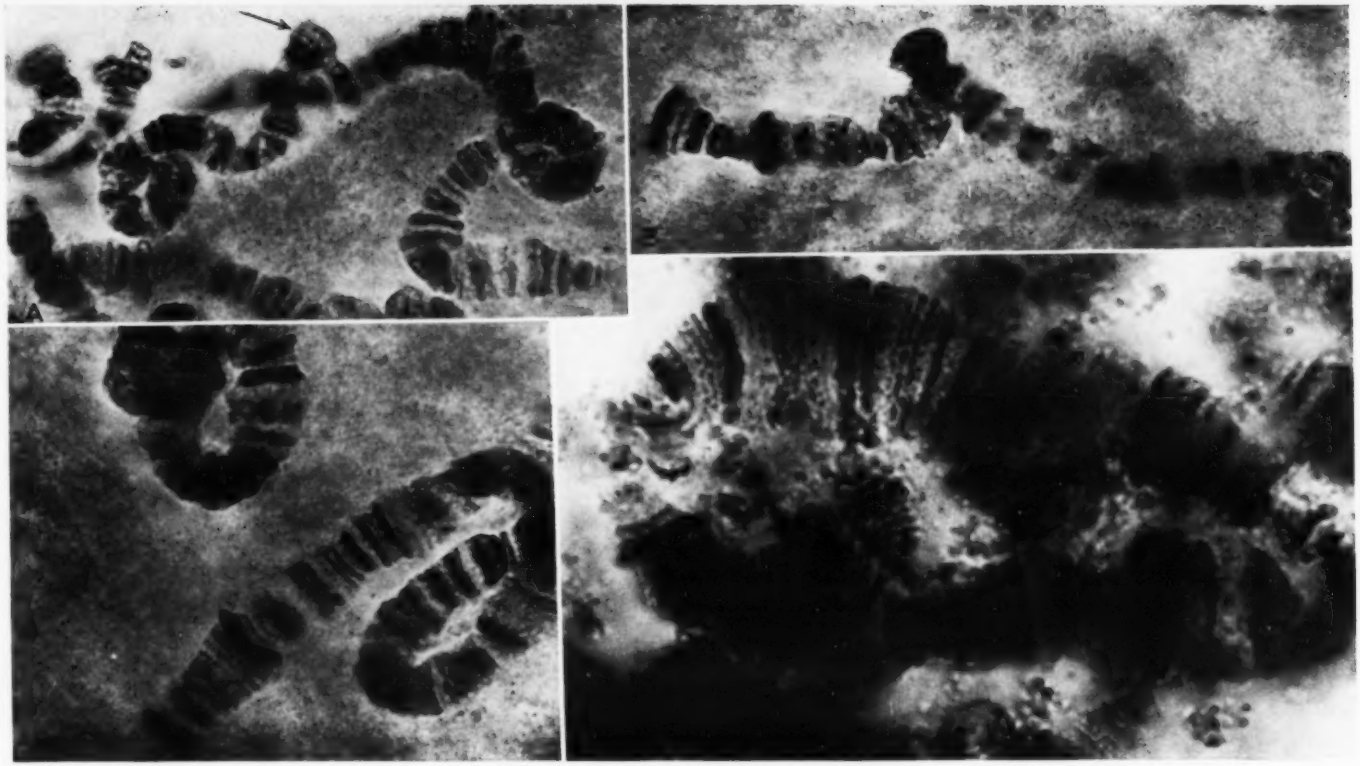
Although the most conspicuous variations in the visible structure are seen, as just noted, in the chromatic segments, our observations indicate that they are actually due largely to differences in the adjacent achromatic segments. In other words, the fixation image appears to be determined to a considerable extent by the achromatic material which, in coagulating, may distort the adjacent chromatic materials. With reagents such as acetic acid the achromatic material shrinks and at the same time takes on a vacuolated or

OTHER END OF CHROMOSOME *A*

Figure 6

Five photographs of end *2* of chromosome *A*. These photographs represent a series comparable to that shown in the preceding illustrations for end *1* of this chromosome. *A* is from the same preparation as *5A; B* is from the same as *5C* and *5E*, and *C* is from the same as *4C*. They show the same general characteristics as the others mentioned, and corresponding influences of the techniques used. In *D* and *D'*, at the point indicated by the arrow a "deficiency" of at least one segment is evident. One chromosome of the pair lacks the structure present in the other. (It must be remembered that each of these chromosomes is a compound structure arising from the fusion of two somatic chromosomes.) This may represent a difference of one gene. The two pictures are made at different optical levels to show that the adjacent segments are really continuous across the double chromosome, although at a high focus they appear separate. The segment noted here is inherited in a regular manner and may be present in both chromosomes or absent from both, as shown by the other photographs. In *A* it is present, while in *B*, and probably in *C*, it is absent. The arrow indicates where it should be in *B*.

(*A, C, D*, 2500×; *B*, 3100×)



PORTIONS OF *X* AND *B* CHROMOSOMES

Figure 7

A—The *X* chromosome pair, from a female larva. In this particular case the end segment of the *X* is fused to one of the segments a considerable distance from the end and the protoplasmic structure is continuous from one segment to the other. The apical segment is seen in end view; the other in side view. From an iron-aceto-carmine preparation. *B* and *C* show end *I* of chromosome *B*, from an iron-aceto-carmine preparation, to show details of structure and characteristic segmentation. The swelling a short distance from the end is usually more pronounced than in these cases. The condition shown in Frontispiece is more nearly typical. *C* shows a portion of a chromosome from a preparation treated with osmic acid followed by formalin and then iron-aceto-carmine. As noted above (Figures 4*C* and 6*C*) this method makes the chromosomes very granular in appearance (due to the osmic and acetic acids). Note the large number of granules in the chromatic segments here, and the fact that in some cases the granules are so small and close together as to make continuous "bands" with as many as twenty granules in a "band." (*A-C*, 1300×; *D*, 2300×)

alveolar appearance. The different achromatic segments apparently differ in their response to fixation and produce corresponding differences in the adjacent chromatic segments. These two factors together, in our opinion, account for the various types of structures found in the chromatic segments, as mentioned above. On this interpretation the number and size of the "granules" seen in some segments, depends on the manner in which the adjacent achromatic material coagulates. Also the appearance of swelling in some of the chromatic segments is not due so much to actual swelling of these structures, as to shrinkage of the adjacent achromatic materials.

It seems particularly significant that different achromatic segments give different fixation images. This is interpreted as an indication of corresponding differences in the protoplasmic materials in these segments, and as suggesting that the achromatic materials may possibly be genic in nature.*

Relation of the Segments to Genes

No attempt will be made here to discuss this topic in detail, but a few salient features may be mentioned. Belling[1], in his remarkable studies on the lilies, has provided strong evidence that the chromioles or "ultimate chromomeres" in chromosomes actually represent the genes. Since it seems probable, on the face of the evidence, that the chromatic segments in the salivary chromosomes represent the chromioles or "ultimate chromomeres" of Belling, these chromosomes afford an excellent opportunity to test the hypothesis.

Painter and others have shown that the chromatic segments in the salivary gland chromosomes of *Drosophila* bear a definite relation of some kind to genes, and Koltzoff[8] and Bridges[2] have interpreted the individual "granules," sometimes seen in the chromatic segments, as representing genes. The latter interpretation considers the salivary gland chromosome as a compound of eight or sixteen spirally disposed chromonemata, bearing granules which represent the individual genes, or (on Koltzoff's view) the spaces between the genes. It considers the chromonemata as having been derived by repeated division of the original chromonema of the parent chromosome, without division of the chromosome itself. The interpretation is supported also by the observation of spiral or longitudinal striations in the chromosomes, connecting granules in successive segments.

Our observations, as already indicated, lead to a different interpretation from that just cited. In *Sciara* we find that the "granules" in the segments vary in number and that the numbers do not seem to fit the requirements of the latter interpretation. The results apparently depend on methods of fixation, etc. Likewise, we would interpret the striations as due to twisting or stretching the chromosome, since they seem to appear only in regions which have been distorted and since they do not appear to be continuous threads, but rather to form part of a branching network.[13] It may also be noted that if the chromosome is compound in the sense suggested by Koltzoff and by Bridges, and owes its size to repeated internal division, as suggested by these authors, we would expect it to be composed of hundreds of "strands" or chromonemata, instead of a small number like eight or sixteen, for it is probably thousands of times as large as it was originally (at the last mitosis).

In our material the "granules" do not appear to be discrete bodies, but to represent chromatic material lying in the interstices between what appear in fixed material to be alveoli, or vacuoles. They are elongate, and may be traced up and down in irregular paths between the "alveoli" (Metz and Gay[13]). So far as we have been able to observe they do not radiate out from the axis of the chromosome. In transverse optical section a somewhat similar granular structure is visible, with the granules bearing the same relation to the

* See also Koltzoff[8].

alveoli; and apparently this type of structure extends entirely through the chromosome transversely, without being interrupted by a central core. If a thick segment lies in the optical section it appears as an essentially uniform, dark disc, extending through the chromosome transversely. We have not been able to detect any subdivision of the segments into radially disposed units.

As to the relations between the chromatic and achromatic materials our observations suggest that a gene "locus" may include both, i.e., a chromatic disc and the achromatic disc or segment adjacent to it on one side. The evidence on this point, however, is inconclusive.

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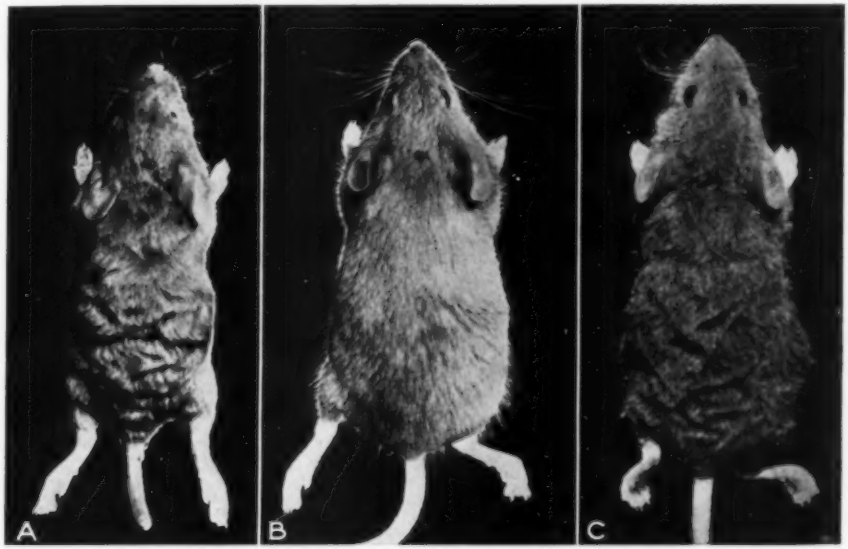
Anencephaly in Twins

The birth of a pair of twins, probably identical, both lacking brains, was reported and illustrated by Dr. K. B. Waller in the *Canadian Medical Association Journal*, July, 1933. This condition is extremely rare and apparently this is the first occurrence in twins to be recorded. The family was of low grade mental development and the author is of opinion that the anencephaly may have had a genetic basis.

A SECOND REXOID COAT CHARACTER IN THE HOUSE MOUSE

CLYDE E. KEELER

Howe Laboratory, Harvard Medical School and The Bussey Institution



TWO CURLEY HAIRED MUTATIONS IN THE MOUSE

Figure 8

Photographs of a normal coated mouse (*B*) and of two very similar but genetically distinct curley haired mice,—"waved$_1$" and "waved$_2$". The "waved$_1$" mutation (*A*) appeared in Doctor Crew's laboratory in Edinburgh. The "waved$_2$" mutation (*C*) appeared at the Bussey Institution in Boston. First generation crosses between "waved$_1$" and "waved$_2$" individuals have a normal coat, proving that two distinct genes are involved.

DURING the winter of 1932 Mr. Cuthbert Daniel of the Cambridge School procured some of my "Berlin Blaze" stock of laboratory mice as demonstration material for his class in biology. In a litter produced by these animals there was an individual which developed a wavy condition of the coat recalling the "permanent wave" coiffure so popular with ladies of to-day. We called the variation "marcelled" and attempted to perpetuate it. Unfortunately, the mutant and his parents proved sterile in our laboratory, and hence we lost the stock.

In 1933 Dr. Crew published an account of a "waved" mutant which was discovered in 1930 by Dr. Evelyn Boyd and subsequently studied by Dr. Crew. This investigator reported that the vibrissæ of Boyd's mutant are seen to be curled upon the 4th-5th days; that the coat shows waviness upon the 7th-8th days; that waviness of the coat increases up to the 7th-8th weeks, after which it disappears. We may add to this description our observations that Boyd mutants are usually smaller and weaker than their normal litter mates, and may be distinguished from normals at birth by their shorter vibrissæ, which are visibly bent as early as the

second day. When the general coat is most waved, the guard hairs are frizzled. Most of the mutants may be distinguished from normals throughout life by their shorter coat, curved guard hairs, and the irregular direction of the hair upon shoulder, back, and thighs. Many retain a curvature of some individual vibrissæ.

The photograph of a waved mouse descended from Dr. Boyd's mutant is shown in Figure 8*A*, and that of normal mouse in Figure 8*B*, for comparison. Mr. Daniel's mutant corresponded closely in all particulars to Dr. Boyd's "waved" mutant. But there are known in the domestic rabbit three genetically distinct, although phenotypically indistinguishable, rex mutations, and at least two and possibly three rex variations in the Norway rat. These all resemble the "waved" mouse. Hence, mere resemblance between Mr. Daniel's "marcelled" and Dr. Boyd's "waved" is not a proof of genetic identity.

Shortly after Dr. Crew's paper was published, there appeared in my "abnormal Corpus callosum" stock another wavy mutant. The photograph of a waved mouse descended from this mutant is shown in Figure 8*C*. This stock was not related to the "Berlin Blaze" stock, and hence it appears unlikely that both mutants could have had a common origin.

This mutant we shall name "waved$_2$" in contradistinction to Dr. Boyd's mutant, which we shall call "waved$_1$." "Waved$_2$" mutants may also be distinguished at birth by their smaller size and shorter vibrissæ. The vibrissæ are bent upon the second day, and distinctly curled by the 4th-5th days. Waviness appears as soon as the coat develops upon the 7th-8th days. Waviness of the coat increases from the 4th to 6th weeks. When the coat is most waved, the guard hairs are frizzled. During the 7th-8th weeks waviness decreases. Waviness may disappear entirely or may be evident to a slight degree throughout life. Vibrissæ usually remain curled, guard hairs curved. The length of coat remains definitely shorter than

NEW BORN MICE SHOW WAVY GENE
Figure 9

The baby mouse on the left is normal for hair form; that on the right is a homozygous recessive for the "waved$_2$" gene. Note that the vibrissae ("whiskers") of the waved mouse are distinctly shorter than those of the normal. The "waved$_1$" mice also show this difference at birth. It is noteworthy that two genes which are so remarkably similar in their action are entirely distinct and independent in inheritance.

that of normals, and the hair angle remains irregular.

When "waved$_2$" is compared with "waved$_1$", it is impossible to distinguish them except by the fact that my "waved$_2$" individuals are more extremely "marcelled," have slightly shorter hair on sides and belly, and their vibrissæ are more curled than is the case with those specimens of Boyd's "waved$_1$" mice which I have examined. But because the range of expression of neither "waved$_1$" nor "waved$_2$" is worked out, even these possible distinctions between the two mutants may be only apparent and not real.

The original "waved$_2$" mutant was a male. He was outcrossed to four unrelated females. A total of 22 hybrid mice were produced, each of which developed a normal coat. This test proved "waved$_2$" to be a recessive character.

Next, the "waved$_2$" mutant was mated to "waved$_1$" females. A total of 27 young were produced from these matings, all of which were normal coated. This corroborated our previous findings that "waved$_2$" is a recessive character and demonstrated further that it can not be produced by the

"waved$_1$" gene or an allelomorph of that gene.

The "waved$_2$" mutant was mated to three related females. These matings produced 55 normal and 49 "waved$_2$" mice. Equality of numbers is expected in these crosses if "waved$_2$" is a Mendelian recessive character. This proved that the condition is due to a single pair of recessive genes for which the females were heterozygous and for which the "waved$_2$" mutant was homogygous.

The possibility that "waved$_2$" is a sex-linked recessive character is precluded by the fact that when "waved$_2$" females were mated to an unrelated normal male, 20 normal males were produced, whereas if the character were sex-linked, all the sons of "waved$_2$" females must of necessity be "waved$_2$".

"Waved$_2$" is being tested for linkage with the other known genetic characters of the mouse.

Summary

"Waved$_2$" is a recessive autosomal unit-character of the house mouse similar to the rex characters of rabbits, phenotypically indistinguishable but genetically distinct from Boyd's "waved$_1$".

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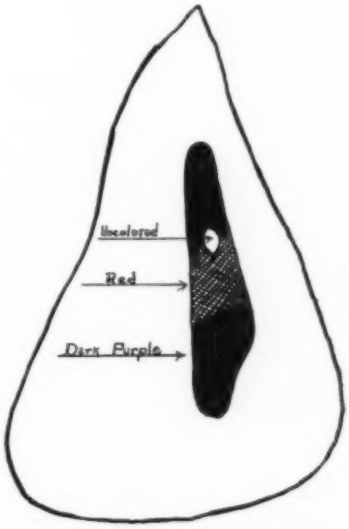
A MULTIPLE MOSAIC IN MAIZE

THE Brahma-Plymouth Rock mosaic described in the Journal of Heredity for January, 1935, by Roberts and Quisenberry is thought by Castle to be due to fertilization by more than one sperm. (Journal of Heredity, February, 1935). In a reply to Dr. Castle, Roberts and Quisenberry pointed out that this interpretation does not adequately account for the loss of the dominant color extension factor. A mosaic in maize aleurone involving at least two, and possibly three genes, in different chromosomes, that could not be due to abnormal fertilization, may help in understanding this curious phenomenon.

A yellow sweet corn with the aleurone color formula of *A C r pr i* was pollinated by a white pop corn having the aleurone composition *A C R Pr I*. Normally the seeds resulting from this pollination have no aleurone color but in this particular combination 1 in 29 seeds showed varying sized patches of purple aleurone. These mosaic areas are due to a loss of the dominant *I* gene inhibiting color. In one seed among 3,448 there was found the mosaic that is diagramed in the accom-



THREE GENES LOST

Figure 10

These color changes in the aleurone layer could only be due to progressive loss of genes from different chromosomes. Multiple fertilization would not account for the phenomenon.

panying illustration. The solid black part is colored a dark purple, the central section red, and the small uncolored spot is the same as the uncolored part of the seed. This triple mosaic seems to be due to a successive loss of three genes: *I*, *Pr* and *R*, located in chromosomes 9, 5, and 10. The loss or inactivation of *I* allowed color to develop, the loss of *Pr* changed the color from purple to red, and the loss of *R*, one of the three complementary factors necessary for the expression of aleurone color, prevented any color from appearing. The uncolored spot may be due to a recovery of the *I* gene as described by Stadler (*Proc. National Academy Science*, 16: 712-720, 1930) instead of the loss of the *R* gene.

In this combination all three genes are heterozygous and the dominant allele in each case came from the male parent. Since the entire seed has starchy and yellow endosperm due to the action of the *Su* gene from the male and the *Y* gene from the female, and the entire mosaic is surrounded by normal tissue, there is no possibility of more than two parents. From evidence presented elsewhere (*Proc. Nat. Acad. Science*, 21:90-96, 1935) these mosaics more probably are due to deletions rather than to non-disjunction.

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CORRECTION OF TWO ERRORS REGARDING SELECTIVE FERTILIZATION

TWO correspondents have called attention to additional literature references to selective fertilization which necessitate a modification of two statements made in my recent review of this subject in the Journal of Heredity (26: 17-22, January, 1935).

As regards sex of gametes it was stated (p. 17) that in Mucor and related genera different degrees of plus and minus occur so that a certain clone which acts as plus in one test may act as minus in another. This "relative sexuality," however, does not exist in Mucor, but it has been shown in Dasycladus (Jollos, Victor, 1926, Untersuchungen über die Sexualitätsverhältnisse von *Dasycladus clavaeformis*. *Biol. Zentralbl.* 46: 279-295), Ectocarpus and other algae. In the Mucors there is strict sex dimorphism although different *strengths* of plusness and minusness occur, grading from clones giving a strong sexual reaction down to the "neutrals" showing no sexual reaction either with plus or with minus clones. (Satina, Sophia, and A. F. Blakeslee, 1929, Criteria of male and female in bread moulds (Mucors). *Proc. Nat. Acad. Sci.* 15: 735-740.) I am indebted to Dr. A. F. Blakeslee for calling my attention to this error.

As regards differential maturation it was stated (p. 20) that in plants there is no clear evidence for selection on a genetic basis of one of the four nuclei resulting from meiosis in the megaspore mother cell. Renner, however, has shown in Oenothera that there is competition between the four megaspores as to which shall form the female gametophyte (Renner, O., 1925, Untersuchungen über die faktorielle Konstitution einiger komplexheterozygotischer Onotheren. *Bibliotheca Genetica*, 9: 161-164). While ordinarily the upper three degenerate, one of these may develop if it includes certain combinations of genetic complexes. I have to thank Dr. M. M. Rhoades for calling my attention to this reference.

P. W. Whiting.

GENETICS, PSYCHOLOGY AND ECOLOGY OF MAN AND OTHER MAMMALS

A dozen recent books consider such diverse aspects of a large subject as the History of the Back-bone and the effect of ultra-violet light on twins.

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HUMAN GENETICS IN RUSSIA

VOLUME 3 of the *Proceedings* of the Medico-Genetical Institute of Moscow* is a welcome record of some of the results obtained during the past two years, at the only institution in the world where a really professional attack is being made along a broad front, on the more important problems of heredity and of the relation between heredity and environment in the organism of greatest interest to us—namely, in man himself. Medical literature of the past three decades has demonstrated conclusively that little in the way of important results in this field can be obtained by amateurs in genetics, while genetic literature in the same period shows how seldom worthwhile results in regard to human characters that are of real importance in themselves can be obtained by geneticists who are amateurs in regard to the specifically human problems concerned (*e.g.* in medicine or psychology). Unfortunately there have been hardly any workers, or even groups of workers, combining the necessary specialties and at the same time in a position to carry on such investigations in various directions and on any considerable scale. The Medico-Genetical Institute of Moscow stands practically alone in this respect.† On its staff more than fifty professional physicians, psychologists, etc., equipped with genetical training and working with the cooperation of genetic specialists, have been carrying on studies in fields quite inaccessible to the amateur in human problems and by the help of methods with which only geneticists have hitherto been conversant.

Dominant Defects

The geneticist knows that in order to get a fair picture of the general course of inheritance of a trait in a group of organisms having as mixed a genetic composition as most human populations, it is necessary to have knowledge, not merely of a few but of numerous pedigrees, and these must be studied with due regard to the manner of selection of the material. In a number of the investigations recorded in this volume several hundred pedigrees were collected, which, considering the large size of families prevalent in the region studied, represents a very considerable body of data. Thus it was possible to show, for example, that the occurrence of *diabetes mellitus* is ordinarily determined by one dominant gene, whose expression, however, is strongly influenced as regards both intensity and quality of effect by modifying factors, no doubt both genetic and environmental. Ulcerous disease (also on the basis of several

* *Proceedings of the Maxim Gorky Medico-Biological Research Institute.* Vol. 3, 284 pages (20 articles), in Russian with English summaries. Published by the Government Press of Biological and Medical Literature, Moscow-Leningrad, 1934. Since publication of these proceedings the name of the institute has been changed from "Medico-Biological" to "Medico-Genetical."

† Vogt's institute in Berlin and Davidenkof's laboratory and clinic in Leningrad are doing very valuable genetic work along certain special neurological lines, and there are other institutes whose genetic interest is mainly along "anthropological" lines but which do relatively little critical genetic work on human characters of the greatest intrinsic or methodological importance.

hundred pedigrees) has a similar mode of inheritance. In fact, a continuation of the work along these lines (including that carried out since the present proceedings were published) is indicating that the great majority of hereditary detrimental traits in man are dominants, of irregular expression, and that the current view concerning the prevalence of recessiveness among human hereditary ailments and abnormalities is a misconception. This is a matter of the utmost practical importance.

Having determined the general course of heredity of a trait, we are better enabled to judge which apparently non-affected relatives of affected persons may carry genes for it. Intensive study of such individuals then sometimes reveals signs of such genes. A case in point is that of the results of sugar tests on relatives of diabetics. Thus there may be considerable value for preventive medicine to be derived from the study of the course of heredity of an ailment, and of the detailed phaenotypic expression of the genes concerned in it, since we are thereby assisted in determining among what individuals to look, and for what characters in them to look in order to find warning signs that may help to guide their own specific hygiene and mode of living. On the other hand, a scientific investigation carried out in this manner may also serve to dispose of previous medical misconceptions regarding such signs. For example, the extensive investigations on ulcerous patients reported in one of the articles showed that there was no basis whatever for the current medical view that the so-called "asthenic type" is predisposed to ulcerous disease: it is only the ulcerous disease that tends directly to weaken the patient.

Other papers in the volume bring human genetics into relation with other biological fields. As a contribution towards a future cytogenetics we find the description of an elaborate technique of tissue culture and fixation for determining the cytological picture of any living person. Another paper analyzes possible cases of attached *X*-chromosomes in man. Proceeding into the realm of embryology in relation to genetics, we find a study of the sex ratio of an extensive collection of the human embryos of all ages. It is shown that the excess of males at birth does not depend on a higher death rate of female embryos (at least from the ages of six months, when sex can first be accurately determined), but even exists in spite of a death rate working in the opposite direction, so that there is reason to believe (barring sex reversal) that there is a considerable excess of fertilizations by male-producing spermatozoa.

Twins

About half of the papers in the collection deal with work on twins, of whom over 800 pairs have been studied medically. The mathematician Ignatiev, of the Medico-Biological Institute, presents formulae for the more accurate determination of the relative rôles of hereditary and environmental differences in determining observed differences between the members of a pair of twins, and the other articles on twins use these formulae. An extensive medical study of twin children by Bossik shows a noticeable rôle of heredity in such characters as the time of beginning of teething, sitting and walking, and also with regard to susceptibility to certain contagious diseases of children, such as scarlet fever. On the other hand, in the case of some other diseases, and amongst these most notably tuberculosis, the influence of heredity was found to be practically insignificant as compared with that of environment. This conclusion is directly opposed to the findings of many earlier investigators. Weight at birth, so often taken as an indication of vigor, was likewise found to be practically unconnected with the genetic composition of the child. Similar studies of hereditary and environmental determination on children and

on adults are reported for various other characters of importance in medicine: for example, blood-pressure and pulse rate, where the hereditary influence is very strong; conformation of the sinus system—different parts of which were found to differ greatly in regard to the importance of the rôle of heredity; and the electrocardiogram, which latter was found to be very strongly genetic indeed.

In the case of the electrocardiogram it is shown how, by the use of identical twins, it is possible to discover physiological relationships between one trait and another which would in ordinary data be quite lost to view on account of the great heterogeneity of the individuals with regard to innumerable other disturbing factors. In identical twins, a clear correlation was discovered between the size of the heart and the size of the "T-wave" of the electrocardiogram; such a correlation would have been entirely obscured by other factors in any miscellaneous collection of cases from the general population. There is involved here, then, a general method of potential significance both for physiology and therapeutics.

Results of more direct therapeutic value were obtained from identical twins by using them not merely as subjects for statistical observation but as actual objects for experimental treatment. Thus, when only one member of each of a number of pairs was treated with ultraviolet light in cases of rickets or of broncho-adenitis, the immediate value of the treatment was quite clearly demonstrated, but it was also found—quite unexpectedly—that some months after the treatment had stopped the twin who had not been treated had in each case become superior to the other in general health, resistance to disease, etc. Thus the twin method can be used not only to study the general amount of determination by heredity and by environment respectively in regard to given traits, but, more specifically, it is possible to study the mechanism of action of each in such detailed determinations.

An especially intensive series of studies is being carried out on groups of twin children who live in a special home belonging to the Institute. Some of them are used in psychological and educational studies in which one member of each of a number of pairs receives different training from the other. Great genetic differences between one pair and another, of course, stand out readily, but marked effects, sometimes of an unexpected character, are also found as a result of the controlled difference in training. Thus it was found that certain training in what were superficially merely motor functions, such as rolling a ball, had considerable effect in raising the degree of general activity, independence, discipline and even intellectual level of young children. In connection with another course of training, involving the construction of little buildings by means of blocks, it was found that very different effects were produced on the two groups compared. One of these groups had merely to arrange the blocks after the pattern in which they saw them already lying in a model having the positions of each block visible, while the other group had to make a construction as nearly as possible of the same kind, by copying an identical model which latter, however, was covered with paper so as to hide the actual shapes and positions of the individual blocks used. The latter group of twins learned more slowly and with greater difficulty to make models similar to those presented to them, but they had to work their constructive imaginations in so doing, and at the end of the two months' training (of only a half-hour every other day) this group was considerably superior to the first group not only in constructive ability when this was applied to making edifices with blocks, but also in regard to other activities that might have been considered very remotely related. In a quite general sense, in fact, their geometrical intelligence had become

considerably raised above that of their twin brothers or sisters. Moreover, the effect of this short period of training has been found not only to be general but to be very lasting. By means of such studies, then, new and highly useful paths seem to be opened up in psychology and pedagogy.

In a general article dealing with the results and prospects of the twin investigations, Dr. S. G. Levit, the director and inspirer of the Medico-Genetical Institute, stresses the fact that the relative rôles of heredity and environment do not form a constant ratio, even with regard to any one trait. They vary not only with age, but also with the genetic and more especially with the environmental conditions of the group considered—a fact which has never before been properly taken into account. In the studies of the Institute, therefore, the records of the twins are being classified in separate categories, according to their ages, and especial attention is also being paid to the economic condition, mode of living, etc., of the individuals studied. Moreover, the records are being classified so as to enable a comparison to be made of the results for groups of individuals of a fixed age, in succeeding years. It is expected that, as general economic conditions in the Soviet Union continue to improve from year to year, noticeable differences will appear in the relative rôles of heredity and environment with respect to given characteristics. And this, of course, may be the prelude to a later study of the more specific methods of operation of the concrete factors concerned. Genetic and exogenic studies must go hand in hand if we would attain the desired understanding and control over our own superlatively complicated and important human material, from either the euthenic or the eugenic standpoints, and such studies demand the use both of the highest and most specialized knowledge and of the most refined techniques known in biology, medicine and the other specifically human sciences.

H. J. Muller

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RESEMBLANCES OF ANTHROPOIDS AND MEN

THE subject matter of the book by Zuckerman* was originally prepared for the 1932 meeting of the British Association for the Advancement of Science, the general topic for discussion being "Primates and Early Man." From many sources of information the author has collected a large amount of evidence having a bearing on taxonomic and phylogenetic problems arising in the course of investigations on lemurs, monkeys, and apes. The successive steps in the evolution of man from the lower froms of animal life have been the object of study since the time of Darwin's original contribution, with the main focus of attention in the field of morphology, and in attempts to trace the so-called "missing links." In the investigation of the evolutionary theory, naturally, a correct classification of animal groups is a most desirable procedure, but, as the author emphasizes, one almost impossible to achieve. He believes that a better approach to the desired result could be obtained by including all of the functional or dynamic characters displayed by the animal groups under classification, rather than by limiting the observations to the more static morphological

*Zuckerman, S. *Functional Affinities of Man, Monkeys, and Apes*: A Study of the Bearings of Physiology and Behavior on the Taxonomy and Phylogeny of Lemurs, Monkeys, Apes, and Man. Pp. xviii+203, 24 plates. Price $3.00. New York, Harcourt, Brace and Co., 1933.

features, a tendency which has been dominant in the past.

In keeping with the general trend of the times to consider the *organism as a whole* or as a *totality*, the author does not draw any sharp distinction between function and structure. In the "Foreword" he states "I have freely used the term 'functional character' to refer to any character that is revealed by methods used in the investigation of the dynamic, rather than the static aspects of organisms. In any case the distinction between function and structure in taxonomic discussion is probably largely artificial, since all the processes of the body presumably have a physical basis; gross structure may therefore be regarded as the expression of the peculiarities of chemical processes."

A discussion of the general and special problems of classification in the Order of Primates is presented through the first three chapters. This orientation is followed by a description of the mechanisms of reproduction as differentiated in the groups with subdivisions of the topic dealing with the duration of life, pregnancy, breeding season, reproductive cycle and changes in the sexual skin. Chapter V deals with the characteristics of the blood of Primates from the viewpoint of taxonomy and phylogeny. In this excellent discussion with its critical evaluations of the experimental work and observations on the morphology of the blood elements, the crystallography of the haemoglobins, preciptin reaction, the blood groups and the specificity of the red cells, the biochemist and those interested in comparative physiology, as well as the taxonomists should find many suggestive and stimulating leads to direct additional research.

A short chapter is devoted to the functions of the receptor organs with the main emphasis on visual and olfactory processes, and another comparatively short chapter considers the differentiation of a few selected behavior patterns as observed in facial movements and expressions, drinking, grooming, nursing behavior, carrying the young, etc. Hybridization, affinity and divergence comprise a section of the book in which many morphological, sexual and social aspects of primate life are outlined.

Primate Intelligence

Of particular interest to neurologists and psychologists are the questions discussed in the parts on intelligence, on the comparative findings in the brain, and on the recent investigations of cortical physiology. The researches of Thorndike, Köhler, Yerkes, Lashley, and Fulton and Keller and of many others are duly considered for what they contribute to the small amount of information extant on this important facet of the problem, where detailed experimental correlations between intelligence and brain structure are largely wanting. The physiological and cultural factors operating in the evolution of primate behavior from the lower primates to man present many problematic and often apparently contradictory features, and regarding the transitory steps the author remarks:

> The transition from an ape-like to a human mode of social life, one of the most important phases in man's mental development, may have been largely a matter dependent in the first place upon circumstances arising from without rather than upon circumstances depending on the actual structure of the brain. This possibility clearly suggests the importance of developing studies on the palaeogeography of extinct Primates.

In the concluding chapter the data discussed through the book are briefly reviewed and evaluated in relation to palaeontological and morphological evidence of Primate evolution. From the standpoint of taxonomy "the main points . . . selected for consideration here . . . are arranged in order of increasing taxonomic specificity: (a) the breeding season, (b) facial movements, (c) the serum precipitin reaction, (d) diurnal vision, (e) macular

(stereoscopic) vision, (f) color vision, (g) drinking by suction, (h) finger grooming, (i) the specificity of the antierythrocyte sera, (j) the menstrual cycle, (k) the 'human' nursing position, (l) the sexual skin, (m) the facts of purine metabolism and, (n) the blood groups."

Among the concluding remarks are:

> Man's immediate phyletic relationship to the ancestors of the anthropoid group of Primates cannot be doubted, unless it be argued that he developed the same blood groups, the same serum proteins, and the same peculiarities in purine metabolism altogether independently of the other anthropoids. . . . . Thus in the light of present physiological evidence it is difficult to envisage the basis of a phyletic scheme which links man with any one or with any two of the apes. . . . . Palaeontology is altogether unable to provide the answer to the question of man's precise relationship with the apes.

It is impossible to do justice to a book of this character, in the space of a brief review, and the foregoing remarks furnish only a glimpse of its contents, which should be read carefully by all those concerned with problems of comparative morphology, physiology and psychology. It is a new attempt in the right direction. There is an extensive bibliography covering different fields, a subject index, and an index to the bibliography.

N. D. C. Lewis

St. Elizabeth's Hospital.

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COMPARATIVE PSYCHOLOGY OF MAMMALS

STUDENTS of human mental evolution can profit materially through an intensive acquaintance with facts of animal psychology, especially with the relevant data in regard to the fundamental processes of behavior tendencies and their modifiability in learning. What is instinctive and unlearned is easier to identify and control in animals than it is in man. It is possible, for instance, to set up a family of rats or guinea pigs, or almost any species of domesticated mammal, and to select and restrict the forces operating on development in a way that it never will be possible to do for the human. In fact the development of animal tendencies and their modifiability even before birth have been studied by animal psychologists who, without detaching the placenta, have ingeniously immersed the growing embryo in a saline medium comparable to the intra-uterine environment. From such experiments it is a short step to deductions with respect to the development and modifiability of the human nervous system and structure and its evolving behavior. It is possible to test out, in animals, hypotheses which have been framed in regard to man; it is possible to set up experiments which it would be ethically impossible to set up for man, such as the experimental provocation of genuine emotion in the subjects, or in greater degree the experimental production of insanities of a certain kind; it is possible to select and control breeding in a way that would be psychologically and socially out of the question for the human, and to set up problems,—of mental inheritance for example,—which could be subjected to generations of examination and record. There is of course a limit to the analogy, for in the human mind are to be found traits, ideas, emotions and drives, never to be expected in mammals of a lower order. But this need not impede the energetic animal psychologist from searching for their first faint beginnings.

To assist in the training of these workers, good textbooks in comparative psychology are highly desirable. The symposium offered in *Comparative Psychology** aims to supply such a need. In this book, edited by F. A. Moss, are gathered contributions from some twelve active workers, beginning with an introduction from the veteran experimenter in the animal field, E. L. Thorn-

**Comparative Psychology*, edited by F. A. Moss. $3.50. Prentice-Hall, Inc., New York, 1934.

dike, who points out the advantages which a knowledge of animals will give to the student of man. The late S. I. Franz, another "elder statesman," wrote, —just before his death last year,—a chapter on the neurology of learning. Other participants include the following from among the more brilliant of the younger generation of animal psychologists: P. E. Fields on discrimination, W. T. Heron with two chapters on simple and complex learning, H. S. Liddell on the conditioned reflex, F. A. Moss on the effect of drugs and internal secretions on animal behavior, D. M. Purdy on the functions of the receptors, C. P. Stone, a chapter on maturation and "instinctive" functions, with a second on motivation: incentives and drives. O. L. Tinklepaugh writes entertainingly, as well as authoritatively, on the social psychology of animals, and reviews the subject of "gifted" animals. Many a layman will care to turn to Tinklepaugh's discussion for explanation of horses who can count and do arithmetic and of dogs who can "talk" and carry out rather complicated directions. An able discussion of theories of learning is presented by E. C. Tolman, while R. C. Tryon writes on individual differences.

Bright and Dull Rats

The work of the last named investigator will be of particular interest to students of heredity, for Tryon has successfully bred eight or more generations of rats, selected according to "brightness" or "dullness" in threading a particular maze. Tryon presents some of his own materials, including charts on the effects of selective breeding, the two distributions of animals—bright and dull—showing by the ninth generation practically no overlapping. Here is illuminating evidence on the degree of causation of individual differences in "mental ability" by hereditary and environmental factors. However, satisfying as these results are from the standpoint of method and record, Tryon is becomingly cautious in interpretation.

His work is selected for special mention in this review because it affords an excellent illustration of how problems confronting the research worker in human heredity, especially studies concerned with the elusive mental inheritance, can be approached by the animal psychologist working with mammals. Other material in this volume, contributed by Tinklepaugh, on apes will be of special interest for the same reason.

All in all, the book has been carefully planned, and although written by a dozen different people, rather widely separated geographically, the composite shows a minimum of overlapping in subject matter and treatment. Indeed, as often happens in group projects of this sort, the enlarged scope and breadth of view presented are direct benefits which arise out of multiplicity of authorship, carefully selected, each according to his specialty.

GLADYS C. SCHWESINGER

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CANINE PSYCHOLOGY

IN the past a good bit of legitimate criticism has been aimed at genetic studies for their lack of practical value. We have long known that controlled breeding lies at the base of most of the improvement of plants and animals under domestication. Recently, however, there have been a few studies by scientifically trained persons on the traits of domestic animals which are such as to be of practical importance. The reason for this is fairly obvious. There is, on one hand, an abundance of traits, easy to observe and to record, which are more or less superficial but which affect the animal so obviously that the experimenter cannot well avoid them. On the other hand, traits of practical value soon run into the difficulties inherent in conformation, temperament, and a number of other

complex structural, physiological and psychological conditions.

The authors of *Working Dogs** have intelligently and courageously attacked a complex problem. They have described their results in an interesting manner which should prove stimulating to all practical dog breeders as well as to geneticists.

The book occupies a difficult position between pure and applied science and frankly leans more in the direction of the latter, as it quite properly should.

It is to be hoped that the authors will supplement it by the publication of primary data and their genetic analysis in more complete form. Such a work would be of great value to those geneticists who work with mammals and should encourage many of those who see in such forms challenging, albeit difficult, material.

The reviewer has always felt that dogs, properly studied, would provide a sorely needed foundation for a great deal of progress in comparative psychology. *Working Dogs* fully confirms this belief.

The careful autopsy of the dogs raised and recorded at Fortunate Fields should give valuable data on the development of the various endocrine glands and the possible correlation of these with temperamental and emotional differences. This and a host of other problems will undoubtedly be met as they arise.

The authors frankly recognize that they are pioneering and that this book is of a preliminary nature. Granting, however, that such is the case, the book far surpasses any similar efforts that have come to the attention of the reviewer.

It should be read by all interested in dogs from a humanitarian point of view. It gives without sentimental palaver an unconscious picture of the dog's service to mankind. Its illustrations are simple but eloquent. The snapshot of a liaison dog with the German Army carrying a message to the front line trenches under fire pictures a scene of no little significance to those who know dogs.

It is a great satisfaction at a time when we are apt to lean over backwards in our Teutonic formality in higher education and research to find men who, like the authors, combine a judicial attitude in evaluating their material with an appreciation of its emotional values and who are gifted enough to express both of their approaches in a thoroughly absorbing manner.

C. C. Little

Bar Harbor, Maine

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STATISTICS OF VARIABILITY

THE author of this book† is well known for his statistical contributions to clinical problems and for his researches concerning questions of human constitution. The present publication has grown out of this work. It gives a general discussion of problems relating to organic variability. Statistical methods for the analysis of variation and correlation are discussed. Particular attention is given to the concept "normal," its meaning and definition, its relation to statistical averages, especially with reference to constitutional types. There are many interesting suggestions with regard to technical procedure in dealing with statistical material.

W. Landauer

Storrs Experiment Station

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*Humphrey, Elliott, and Lucien Warner. *Working Dogs.* Price $3.50. The Johns Hopkins Press, Baltimore, 1934.

†Gunther, Hans, *Die Variabilität der Organismen und ihre Normgrenzen.* Pages, 132. Price, 7 marks. Georg Thieme, Leipzig, 1935.

EUGENICS AND RURAL TRENDS

EUGENICS may form the bridge that is needed between the social sciences and the biological sciences, in the interest of agriculture. Sociology has little meaning without eugenics, and eugenics gains a practical outlook only as rural life is recognized as an essential condition. Civilization is a joint product of human ability and of social adjustments. Sociology as the science of civilization, is a field of knowledge adjacent to ethnology, the science of race. Thus sociology and ethnology are biological sciences, or will become biological when they emerge from the philosophic stage of abstract conceptions of race and society. Not only do the plants and animals have social habits and adaptations that need to be studied and compared with those of the human species, but also the applications of sociology necessarily must relate to the qualities and faculties of mankind, as expressed in the several human races.

Sociology in its present state is scarcely to be recognized as a biological science, only one side of the subject being developed, on the border of economics. Sociologists and economists show us the same world of endlessly conflicting interests, industrial, commercial, and philanthropic, and still with no standard for valuing one interest beyond another. The intention of sociology was to replace the "Science of Wealth" by a "Science of Welfare," but for this purpose a different approach seems necessary, from the biological side, to take account of the factors of human development.

Of the need to study the social phenomena there can be no question, nor would objection be made to the collection of any data that can contribute to better understanding, but still there are data and data; and the issues of which and what are not to be avoided, if the quest is to accomplish anything more than tiring ourselves in vain. The tracks that cattle make in milling around their pasture may be recorded in endless detail, and the arts of statistical elaboration could be exercised to any extent. As with a picture or a poem, the technical perfection of "a piece of investigation" may be appreciated by other specialists quite apart from any interest in the subject-matter. The pasture tracks may be classified by size, shapes, positions or directions, and such differences may be correlated with rainfall, food supplies, or other data, yet all beside the question of entering or leaving the pasture.

To what do our vast aggregations of social data really relate? How much is milling, how much is growth, and how much is decay of our social organism? The lack of a basis of practical judgment is the painful reflection enforced in surveying a vast exhibit of social data presented as *Rural Social Trends** by Brunner and Kolb, one of the series of monographs prepared by a special committee as a "study of the factors of change in modern society."

The city is the human milling place, where the struggles for wealth and position are continually going on, but to no eventual human purpose, since all of the contestants are lost. There is only a negative meaning in the urban struggle. The city is not a pasture, but a stockyard. As long as we remain unconscious of the racial hazards of the city, our civilization has no assurance of being more than temporary, like others of the past.

A great discrepancy exists between the actual state of sociology and the popular belief that the factors of social progress are well understood, so that instruction could be given in the public schools, and in a few years everybody might be prepared to exercise judgment on social questions. It is easy to see that such a belief might be generated by vast arrays of data that often appear to

*Brunner, Edmund De S., and J. H. Kolb. *Rural Social Trends.* Price, $4.00. McGraw-Hill Co., 1933.

relate to important questions, but give us no definite bearings.

The essential difficulty in developing sociology as a practical science is to obtain a suitable perspective. While the proper study of man may be conceded to be man, it is also the most difficult. With our lives so completely saturated and immersed in the social phenomena, a selective, constructive consciousness is very difficult to attain, and it is no wonder that sociology has remained backward in comparison with many other sciences that are less directly concerned with our daily lives. The highest grade of human ability is engaged in determining the constitution of the remotest stars, thousands of light-years away. The word sociology was invented only a century ago, and the new science slept rather peacefully for many years after its birth was announced. The revival of sociology thirty years ago, in the writings of Lester F. Ward, carried the warning that "a true sociologist will scarcely have an opinion in a current question." The general difficulties of drawing conclusions from sociological data are stated by Ward as follows:

> In a field so great as that of human society, a wide induction becomes unmanageable. The number of facts to be dealt with is so great that it bewilders the mind. Something must be done besides accumulating facts and drawing conclusions from them. The attempt to reason from the facts of society directly usually results in error. Conclusions so based are unsafe. The historical school of economists sometimes employs this method, but they do not agree in their results, and often err. They attempt to arrive at truth of too low an order to be established in sociology. All the sociologist can do, even in applied sociology, is to lay down certain general principles as guides to social and political action.*

No complaint can be made that any conclusions are drawn from the survey of *Rural Social Trends*. The Foreword, furnished by the Committee, goes even further than Ward, not only in disclaiming the intention of drawing conclusions, but also in stating the difficulties that attend the making of practical applications in the fields of the social relations:

> Modern social life is so closely integrated as a whole that no change can occur in any of its phases without affecting other phases in some measure. Social problems arise largely from such unplanned reactions of the rapidly changing phases of social life upon the more stable phases. To give a few examples: changes in industrial technique react upon employment, changes in the character of adult work affect educational needs, changes in international relations affect domestic politics, changes in immigration policy affect the growth of population and the demand for farm products, changes in consumption habits affect the demand for leisure and facilities for enjoying it, changes in demands for social service by governmental agencies affect taxes and public debts, changes in methods of communication tend to standardize the mode of life in country and city. The effects noted in the list of illustrations in their turn cause other changes, and so on without assignable limits.
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> The usual practice of concentrating attention upon one social problem at a time often betrays us into overlooking these intricate relations. Even when we find what appears to be a satisfactory solution of a single problem, we are likely to produce new problems by putting that solution into practice. Hence the need of making a comprehensive survey of the many social changes which are proceeding simultaneously, with an eye to their reactions upon one another.
>
> If men and women of all shades of opinion from extreme conservatism to extreme radicalism can find a common basis of secure knowledge to build upon, the social changes of the future may be brought in larger measure under the control of social intelligence.

In view of such disclaimers by eminent sociologists there obviously is no basis for the notion of sociology as a science that stands ready to prescribe measures of social improvement.

How far sociology is from considering constructive facts in relation to agriculture may be judged by the complete disregard of eugenics in the outlines of factors and problems. Reference is made to quality of farm population as affected by migration to the city, but only to explain that data have not been collected:

> Unfortunately the census has never published information on the number of urban residents born in rural communities or on farms. The rural-urban migration is a fact too well known to need demonstration; but its amount has never been measured, though

*Ward, L. F. *Pure Sociology*, 49, 1903.

it has been estimated, nor have its composition and quality been investigated save in a few restricted cases. These, however, furnish some basis for generalizing as to certain trends in the rural-urban migration.

The few restricted studies of urban migration are summarized on page 13, to the effect that "the city seems to attract especially the best and the least qualified of the farm youth." That many recent migrants return to the farm, and the reasons they give for returning also are stated:

> Even before the depression, as noted in Table 3, the return from the city to the farm was considerable. Dr. Galpin, of the Bureau of Agricultural Economics, in 1929 asked 10,000 of these back-to-the-landers why they returned. Sixteen per cent said they could save more money on the farm; 14 per cent felt that city work was too uncertain and too hard; 10 per cent liked the independence of farm life; 20 per cent disliked the city; and 27 per cent replied that the city was not a fit place in which to rear children, and that they returned to the farm for the sake of health and better all-round living conditions. Nearly half, therefore, left because of dislike for the urban environment. Seventy-seven per cent of these families had previously farmed. Husband or wife or both of 10 per cent more of the families had been born on farms. The remaining 13 per cent were families with only urban experience.

The motives of welfare are stultified by taking the trends too seriously, as ultimate facts of sociology, or because they have "mass value," as though movements shared by many people must be desirable or necessary, an idea that few would openly avow, but many obey as a "tacit assumption." The migration of millions of Americans to the cities in the war period may be described by historians of the future as one of the mass delusions, like the Crusades or the dancing mania of the Middle Ages.

That many have returned to the farms with clearer convictions of the values of rural living may be the most significant of the trends that the Committee recognized. This effect of the commercial depression, of sending thousands of farmers back to their homes in the country, should be highly appreciated, and may be marked in history as the saving event of our present age. We may regret that a universal economic crisis has been required to make us aware that our so-called prosperity of the war period was only a "get-rich" delusion. Getting all the gold did not keep us from disaster. Shall we learn nothing from such costly experience?

Millions may wish to escape from our over-built cities, but most of the city-bred people find themselves utterly unqualified for the sustained activity of mind and body that are the normal life of "the struggling farmer." The return to rural life will be limited to those who were raised on farms and were not completely urbanized. Subsistence homesteads and other social experiments may be very valuable, even where direct results are negative. The effects of urban incompetence may become so plain as to produce a definite reaction, instead of our social consciousness being formed so largely from urban propaganda.

Population Data

Population data are given in great variety, relating to number, distribution, density, age, education, religion, social organization, medical service, neighborhood changes, and trade relations of farmers with neighboring villages, towns or urban centers, the data running by many routes to the familiar strain of urban expansion and rural depletion in its locally varied forms and degrees in different parts of the country. Tenancy appears in some sections as a state of complete dependence, still close to slavery, while in other sections the tenants were of the same social class as the owners, lived as well, and agreed that they were doing better financially than the owners, "that ownership under present conditions was too arduous, and prevented freedom of movement which they wished to preserve." In other words, "they had become the beneficiaries of the earlier farm ownership and improvement ideal."

Different tiers of counties are compared, and those more remote from cities are found to have higher proportions of children. "The whole population story can be written around this trend of more

children in the outer tiers of the more rural counties. The fecundity and the birth-rate show it, as do the sex and the marriage ratios. Children are a distinguishing characteristic of farm populations removed from urban counties." This fact is seen to have bearing on such problems as the planning of "state-wide courses of study in such subjects as agriculture, civics and vocational guidance," but the pertinence of eugenics in the rural child-zones is not reflected.

The general omission of the eugenic factors from the social problems must mean that our sciences are being built in water-tight compartments. All of the applications of selection in relation to animals and plants, and all of the discussions regarding natural selection and human evolution since the time of Darwin and Galton, have not penetrated to our statistical colleagues, even to the extent of collecting the data that they recognize as necessary for establishing the selective trends of the human population, which are to determine the racial quality of future generations.

The Urban Draft

Biologically there can be no question of the destructive effects of adverse selection, though even in biology much more attention has been given to the plants and animals than to the human problems. Selection is the most powerful agency of human welfare that science has revealed, and we have it working against us without warning or protest. Drafting from the country to the city the more capable members of each generation is more destructive to the race than any kind of warfare thus far invented, because the urban race-mortality, under what we consider as "normal" conditions, is much greater. The better the boys or the girls, the greater their "success" in the city, the smaller their prospect of being represented in the race by descendants in later generations. The farm soldier may survive to raise a family, or may leave children at home to replace their father, but the losses of good people in the city are not replaced or compensated.

Voicing of the hope that the depression may be only temporary, shows that the racial hazards of our so-called "prosperity" were not appreciated in collecting and commenting on the social trends.

> Whether the trends that have been set forth are an index of future developments, and the unprecedented depression of the past three years merely an episode, or whether the changes recorded mark the end of an epoch, it is too early as yet to say. But none can doubt their importance, for within the period under survey, culminating in the decade especially emphasized, rural America felt the full impact of the two forces that have revolutionized the modern world—improved machinery and improved means of communication.

The improved machinery and communications have made it possible to erect a much more extensive structure of social parasitism in the cities than ever before in the history of the world, but the colossal scale of the urban movements is no evidence of their human values. Transportation and communication can be carried to harmful excess, like every other good thing. It was an abuse of these new attainments of our civilization that they were used for many years so exclusively for urban exploitation of the race, instead of being shared with the people in the country, where the needs were greater than in the city.

The children who are being born in the rural "back districts" represent the future of the race, not the people in the city. Sanitary improvements that are confined to the city only increase the racial handicap by drawing more of the capable elements of the race into the current of urban elimination. The selective reaction of urbanism on the rural population is the essential question. There is no objection that smart, weak people should go to the city, to lead sedentary, sheltered lives, or that defective, mediocre, miserly, or trifling people should go, but that the best farm families should be lost, the healthy, capable, right-minded people, is a racial calamity, not to be compensated by any urban accomplishment. The race must be immunized against urbanism, and ways must be found for sharing with

the country all of the real advantages that the city has had, through the advance of civilization.

The method of trends, as carried over from economics to sociology, has its uses and its dangers. The general idea of social changes through modified trends is not without value as keeping in view the essential fact that the social relations form a functioning system which may be constructively modified but not suddenly suspended or torn down for rebuilding, as casually proposed by temperamental revolutionaries "who want nothing but chaos." To insist that destructive, irresponsible revolutions are the only means of progress, because the French or the Russian revolutions fell into such courses, is to forget all of the progress that has been made by measures of reform that have "modified the trends" of society without impairing its structure and functions.

O. F. Cook

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COMFORT FOR PARENTS

THE rearing of children is becoming an increasingly complex matter. In an earlier day the child's physical needs were taken care of mostly on a traditional rule-of-thumb basis. For guidance in mental and spiritual needs the Bible has held a unique position in Christian countries. Since scientific methods (more or less) have been applied to many angles of child development the modern parent has encountered a perplexing mass of increasingly complicated and often conflicting information and advice. Rather early in the new day one phase of the problem was simplified for distracted parents, and for the early months of the child's life a "new bible" almost might have been said to have appeared in the numerous editions of the late Dr. Emmett Holt's *Care and Feeding of Children.*

Unfortunately for parents' peace of mind, children do not continue in the nursery, and as they range continually farther and wider the plight of the parent ever becomes more complicated. An attempt to make a handbook for the parents of today that would do for them in all fields of child activity what Holt did for the nursery child of the previous generation is a venture that should be widely heralded, and if well done, should deserve the reward of as many editions as Holt. Such an attempt is made in *Our Children.** There are four groups of discussions—the child's growth and development; the child at home; the child at school; and the child in the outside world. It is a book worth having and using. We hope it will be revised and extended perhaps to the extent that one person will rewrite much of it, for Holt's appeal perhaps depended on a certain unity and simplicity which few symposia can hope to attain. It is almost impossible for twenty-nine authors of twenty-nine chapters to make an entirely readable and coordinated book.

A valuable addition is a small list of selected references for further study at the end of each chapter.

G. M. Darrow

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HEREDITY IN THE VERY YOUNG

OF the three brochures listed below† the first-named, whose title promises most of interest to the geneticist, is actually the least satisfactory. Lesage doubtless does service in pointing out, to those who are not already aware

**Our Children.* Edited by Dorothy Canfield Fisher and Sidonie Matsner Gruenberg. Price $2.75. Viking Press, 1932.

†Lesage, A., *Enfance et Hérédité.* Pages 104, 6 figures, 10 plates. Price, 20 francs. Vignes, H., and G. Blechmann, *Les Prématures.* Pages, 159, 40 figures. Price, 20 francs. Vignes, H., *La Durée de la Grossesse et ses Anomalies.* Pages, 96. Price, 15 francs. (Collection Médecine et Chirurgie Pratiques.) Masson et Cie, Paris, 1933.

of it, that pathological conditions in infancy are not necessarily acquired, due to improper nutrition, etc., but may be congenital or, as he says, hereditary; hence, the pediatrician should be on the lookout for stigmata of congenital weakness which are likely to manifest themselves in many, if not all, cases of infantile disorders. Heredity as such is not treated in the volume, except for a tabulation of "hérédités morbides" where, in accord with his confusion of the hereditary and the congenital, the author makes no distinction between heredity and intra-uterine injury, etc. A chapter is devoted to the symptomatology of the now somewhat obsolete "arthritic diathesis," and the volume is concluded with a number of X-ray photographs of defective infant skulls with diagrams apparently designed to assist in diagnosis by means of such X-rays.

The two remaining volumes at hand are notable for the fact that the problems are approached by no means from a narrow clinical angle, but from a refreshingly broad biological viewpoint.

Vignes' section on the physiology of the prematurely-born presents a concise review of pertinent material on foetal growth and embryo-chemistry, as background for a consideration of the physiological handicaps of premature birth. This may be of more than casual interest to the geneticist, as it suggests, for example, that specific deficiencies may be produced by a general retardation of development, or by an acceleration of parturition, since the times of origin and rates of elaboration of various substances in the embryo differ widely. Blechman's section in the same volume (pp. 75-159) deals with the clinical diagnosis, care, and therapeutic treatment of the prematurely born.

The volume on the duration of pregnancy opens with a brief chapter on the question of the time of conception, collating, with little or no critical comment, the work of Ogino, Knaus, and others. Other subjects dealt with include the physiology of parturition, the normal period of gestation, abnormalities due to premature birth, and the question of delayed parturition. Again, it is gratifying to find that the position of the author as an obstetrician does not deter him from considering his subject as a biological, rather than a merely clinical, problem.

PAUL R. DAVID
Storrs Experiment Station

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MAN IN PREHISTORY

A MOST fascinating account of man's origins, so far as they are now known, is given in *Adam's Ancestors.**

The author has combined interest with authenticity, an ideal all too seldom attained by writers attempting to popularize scientific information. One gets a picture of both the method and the facts of prehistory. The author presents new materials and new interpretations of older findings in the light of what is now known. From the very nature of the case all of his colleagues will not agree with his conclusions, and this the author himself recognizes.

To the reader interested in heredity and evolution, the following excerpts from the book can best express what the author has to say on this aspect of his subject.

Perhaps some readers of this book, when they realize that prehistory has now traced back man of our own type to the beginning of the Pleistocene and has shown that he was contemporary with various other more primi-

*LEAKY, L. S. B., *Adam's Ancestors.* Price, $3.20. Longmans, Green & Company, New York, 1934.

tive types of man and not evolved from them, will begin to think that here is evidence which is contrary to the theory of evolution. It has been suggested to me that since the results of our work show that *Homo sapiens* has changed so little in the long period of time known as the Pleistocene, this may be taken to indicate that this type of man has his origin in a special creative act, and is not the result of any normal evolutionary process.

This is certainly not the interpretation which I would put upon the available evidence. I should say rather that we have learnt that evolution has been very much slower than we have sometimes been led to believe. The presence of four completely different types of man at the beginning of the Pleistocene suggests to me that their common ancestor must be looked for in deposits at least as old as the Miocene period. The further fact that in deposits of Miocene Age we have evidence of the existence of anthropoid apes very akin to those still living today must suggest that the common ancestor of man and the anthropoids will have to be sought in deposits of still greater age. There can be little doubt now that man has been in existence upon the earth much longer than the million years assigned to the Pleistocene period.

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HISTORY OF THE BACK-BONE

DOCTOR GADOW'S lamented death left this book* in an unfinished condition. The earlier chapters had been largely arranged in order, but the later discriptive chapters were separate, although notes indicating their probable sequence were found. The Editors are responsible, therefore, for the final arrangement and for the introduction of chapter XV. (A classification of the Tetrapoda.) Their work of editing seems to have been sympathetically done and the completed work is doubtless as the author would have had it had he lived.

Doctor Gadow had long been a student of the vertebral column in all of its various modifications and he speaks as one having authority even though at times out of agreement with past and contemporary interpretation of the various elements which go to make up the back-bone. The possible external origin of the axial skeleton is first discussed, followed by the formation of the metameric vertebrae and the composition of a standard vertebra from four primitive cartilages on either side. He notes that every one of the possible combinations and permutations of these fundamental blocks has materialized in some vertebrae of some individual, species, genus, or larger group, and that it is the morphologist's business to trace and try to arrange these variations in lines, and so to find out whether these lines are true indications of affinity and descent, or whether they are instances of convergent or parallel evolution.

One of the main tasks of the present work is to bring order into chaos, with a view to arrive at, or help towards, a natural classification of the many thousands of living and extinct vertebrates. In many cases it is difficult to ascertain what has happened. Interpretation of a particular bony unit may be helped by ontogenetic observation and, if backed by fossils, may be of supreme importance. The author feels that it is as wrong, however, to base a classification solely upon one organic structure, such as the vertebrae, as to base it upon any other organ, whether it be the temporal arches, now largely used in the classification of the reptiles, the convolutions of the gut, the characters of carpus and tarsus, the nervous system, or the sacrum. In spite of this

*Gadow, H. F. *The Evolution of the Vertebral Column.* Price, $6.75. The Macmillan Company, New York, 1933.

Doctor Gadow does use the vertebrae as a fundamental aid to such classification, having given in chapter VII the further development of the fundamental plan of vertebral origin, rendered clear by colored schematic drawings; the origin of the vertebral processes, the articulation of the vertebrae, the evolution of the occipital joint, of the second vertebra of the Amphibia, of the first three vertebrae together, and also of the ribs. The author then discusses the main types of vertebrae; the pseudocentrous, autocentrous, and notocentrous.

Doctor Gadow is now ready for the systematic discussion, taking up the various orders of vertebrates in a sequence which seems logical even though not in accordance with that generally accepted, for mammals appear in the midst of the reptiles and the final group is avian, except for the sea rovers, Ichthyosaurs and Plesiosaurs.

One feels that Doctor Gadow is inclined toward a mechanistic view of evolution. He also quotes Sir Arthur Smith-Woodward's remark: "that the success of a new group depended upon the right time and sequence of the introduction of new organic inventions. 'Too early,' if incompatible with already existing features, was and is as fatal as 'too late.' This kaleidoscopic game has been played since the beginning of life, and this is in the long run the supreme and only test."

In speaking of the bizarre *Dimetrodon*, a Permian finback form, Gadow says that the neural spines which, although slender, are rapidly elongated from the second vertebra onwards until those in the middle of the trunk reach a length of 3 feet, in an 8-foot animal; and then steadily decline towards the tail. Looked at as a whole, these spines irresistibly suggest a sail, which, however, could not be lowered, and, from a sailor's standpoint, is trimmed too flat to be of any use except, perhaps, with a quartering wind. The whole structure was unfit for offence or defence, an excellent case of hypertely, the result of the cumulative inheritance having gained so much momentum that a once possibly useful structure, as spiny crests are, brought about the ultimate destruction of its owner. And yet *Dimetrodon* had a long innings and the still more exaggerated *Naosaurus* is known by various species from Russia, Central Europe, Ohio, Texas, and New Mexico. Thus there was a distribution in time and space of what was more than an ephemeral and localized freak, indeed a successful type in which it took natural selection a long time to find the inherent weakness; but then, as usual, it was finished off quickly.

The order of Dinosaurs as such is morphologically rather disappointing because of the marked indecision of progressive evolution, notable in almost every region of the skeleton, particularly in the skull, hind-limb, pelvis, gait and vertebral column. Some begin well, orthogenetically improving certain parts, then stopping long before the morphological terminus is reached, but transferring active evolution to other organs without necessarily producing high-class specialization; or in the middle of their career they revert to an obviously ancestral condition.

Perhaps all this vague "planless" evolution happened and continued so long, thanks to the absence of dangerous competition, except such as appeared within the whole group itself, that many tried to overcome this danger by force which to them meant size, certainly not brain.

One could continue to quote profitably from this admirable book. The style is lively and at times amusing and, in spite of the necessary technicality of much of the descriptive part, one's interest never flags. The volume is well printed and is highly creditable to the publishers as well as to the author and his editors.

Richard S. Lull.

Yale University

AN EIGHT GENERATION EXPERIMENT IN INBREEDING SWINE

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INBREEDING has long been a subject of considerable controversy. In nearly all our major breeds advantageous use has been made of inbreeding to fix type; and nearly all breeders who have made a lasting contribution to livestock breeding have practiced some inbreeding. The consensus of opinion among livestock breeders, however, is that inbreeding in itself destroys something within the stock on which it is practiced. Biologists, in general, entertained a similar view until this view was proved incorrect by Castle.[1] Castle's studies reopened the whole fundamental aspect of this problem. King[8] and Wright,[13] in their well known experiments, demonstrated, independently, that a rapid approach to a homozygous condition in the mammal may be accomplished without loss of valuable characters. King had rats at the close of twenty-five generations of continuous brother-sister matings more vigorous than her original stock.

During the past twenty years plant breeders have capitalized on inbreeding as a method of improving farm crops. Animal breeders have been much slower to study the advantages of inbreeding as a method of improvement. This has been due, in part, to the time involved in experiments of this kind. During the last 12 years, however, a number of inbreeding experiments with larger animals have been initiated in this country. Several of these have been reported in the JOURNAL.

The University of Minnesota has succeeded in making full brother-sister matings of registered Poland-China swine for eight successive generations without any marked loss of vigor, and the indications are that at least two lines can be carried on indefinitely. Chance selection of strains especially free from recessive deleterious characters probably accounts for these results. This project was started in 1924 at the Southeast Experiment Station of the University located at Waseca, Minnesota.

Objects of This Experiment

The objects of this experiment were:

1. To determine the possibility of developing a strain of swine approaching complete homozygosity and yet retaining the desirable characteristics of the breed.
2. To determine the usefulness of close inbreeding as a method of swine improvement.

Method of Procedure

Full brother and sister matings have been made as a means of developing the inbred lines. This is the closest possible form of mating in bisexual animals. Litter mates were used if possible, but in a few cases it was necessary to use individuals from different litters.

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†The author desires to express his appreciation for advice and guidance throughout the period of investigation by Dr. Andrew Boss, Vice Director of the Minnesota Agricultural Experiment Station; Dr. H. K. Hayes, Chief, Division of Agronomy and Plant Genetics; Prof. W. H. Peters, Chief, Division of Animal Husbandry; to Dr. F. R. Immer, statistical adviser, and Professor E. F. Ferrin, Division of Animal Husbandry, who have advised on statistical procedure and growth studies. He is especially indebted to Dr. L. M. Winters of the Animal Breeding Section of the Division of Animal Husbandry, for assistance in the presentation of data and the preparation of this manuscript. The histological studies, artificial insemination and some of the breeding tests were conducted by Dr. Winters. The author desires also to acknowledge the exceedingly loyal and helpful service of Mr. Howard Greeney, in caring for the animals and recording data.

To guard against loss of the line, each pair of hogs was retained, if possible, until their offspring reproduced. Selection of the best phenotypes was made when a choice offered, although in many instances selection was entirely a matter of ability to reproduce.

Six bred sows were purchased, one representing the extreme chuffy type, one the extreme big type, and four the medium type. One of the latter was used to develop an outbred line which has served as a check stock. The other five were used in an attempt to develop inbred lines. Three of the lines, including both extremes, were lost in the first generation. One of the remaining two was lost in the third generation, due to reluctance to mate. The fifth line has been carried to the fifth generation, but the type is undesirable.

Two new lines were started in 1926. One was from a pair of pigs secured from the Central Station at St. Paul. This pair was out of an outstanding litter and possessed what a Poland-China breeder would call a very good pedigree. The other was started from the out-bred line. These two lines have been propagated successfully. One line is in the sixth generation and the other in the eighth.

Each family, or line, has been designated by a letter and each pig has been given a name beginning with that letter and an individual number designating the year in which it was farrowed. Litters have been numbered each year as they arrived and the pigs of each litter numbered consecutively. Thus, Nella, L1 No. 8-862, was the eighth pig in the first litter born in 1928 and belonged to the "N" line. Registration has been maintained on all individuals used for breeding. The number of generations of inbreeding is given by the symbol I_x, an I_3 pig being the product of three generations of brother-sister mating.

The sows were farrowed in a central house and moved to pasture as soon as feed was available. Pigs were weaned when eight to ten weeks old. Males were all kept on a farm half a mile from the females, except during the breeding season. Both lots received very similar care.

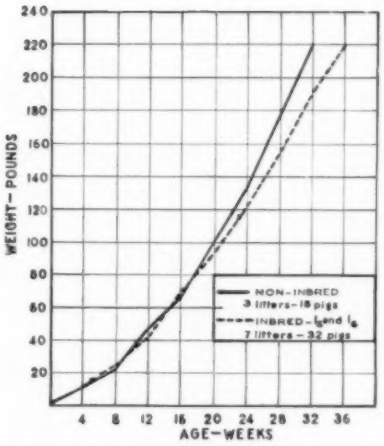
Experimental Results

Difficulty in mating.—All matings were made under observation, the individuals being separated at other times. Boars, particularly of the second and third generations, have shown reluctance to mate with litter sisters. Males quick to serve unrelated sows were completely indifferent to litter mates. In a few cases individuals of different litters were used. They appeared to mate more readily, but the number is too small to be conclusive. Boars have identified litter mates instantly, even in a lot of 25 gilts and after having been kept on different farms for over six months. Perfume, kerosene, and other nostrums were ineffective in preventing recognition.

One I_2 boar proved especially interesting. A few grade Duroc Jersey sows were secured for testing the boar's willingness to mate. This boar's litter mate and one of the Duroc Jerseys showed pronounced heat at the same time. The boar and his litter mate would be taken from their pens and placed in a long alley to which the other pens opened. He would repeatedly walk right past his litter mate to the other end of the alley and rant in front of the Duroc Jersey pen.

All sorts of schemes and devices were used to induce mating. The most effective method has been to endeavor to raise all boars from as many litters as were available in each generation; usually some would mate with litter sisters. Two lines were lost, however, because of failure to mate.

Since the fifth generation there has been less difficulty in securing matings. A few litters were produced the boars of which refused to mate; but in most cases a service was secured within an hour or two if the sow was at the height of oestrum when turned with the boar. Occasional cases were noted, in the advanced generations, where the boars appeared to prefer litter mates to unrelated sows.



GROWTH RATE OF INBRED SWINE
Figure 11

Brother-sister matings for five and six generations resulted in a slightly slower growth rate after an age of sixteen weeks was reached. The averages were lowered by a few slow-growing individuals, and some of the inbreds showed as rapid weight gains as the controls.

Pregnancy has almost always resulted from satisfactory services. This is true even of the cases where great patience was required to induce matings. The few exceptions are no more than would be expected in any herd.

Size of Litter.—Vaughan gives 7.49 as average litter size for medium type Poland-China swine. The numbers of litters in the various groups in this experiment (Table I) are small but rather interesting in this connection. The average of twelve litters of non-inbreds is 9.2. The average litter size for the entire inbred population is 7.1. The most interesting and valuable point in this connection is that a number of comparatively large litters were produced in the advanced inbred generations of both the "M" and "N" lines. This proves that inbreeding of swine can be carried on without adversely affecting prolificacy.

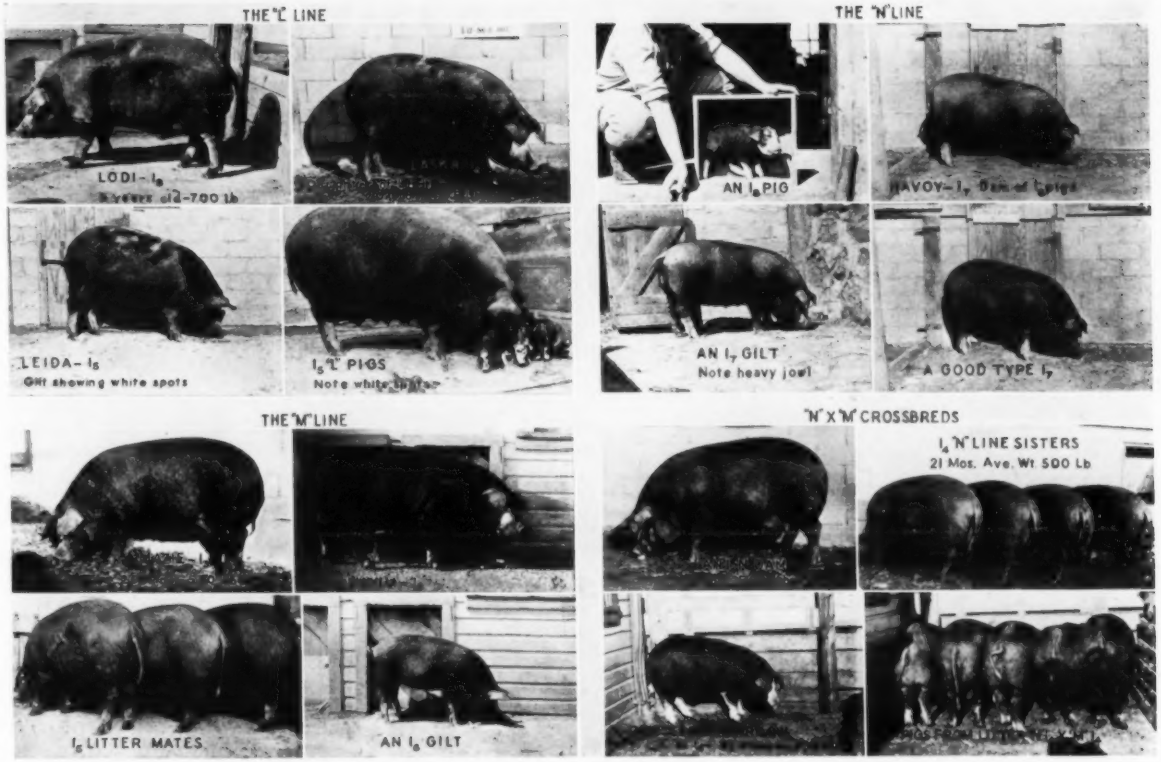
Weight of pigs at birth.—There is little difference in birth weights between the advanced inbred generations and the non-inbred pigs (Table II). The variations in birth weights cover a similar range. The two heaviest pigs born weighed four pounds each; one was an inbred and the other a non-inbred. Non-inbred pigs have weighed as little as 1.1 pounds and inbred, 1.2. The inbreeding has not been accompanied by decreased birth weight.

The survival of pigs after birth.—From the economic standpoint, the survival of pigs is much more important than birth weight, but it is much more difficult to measure accurately. In most instances it is impossible to determine if a pig died because of inherent weakness or because of accident, i. e., many accidents might never have occurred had the pigs possessed more vigor or the mother a different temperament. For this reason no attempt has been made to keep an accurate record of the cause of death.

The loss of small pigs has been rather heavy (Table III); although among the non-inbred and the "N" line, it is distinctly less than the average given by Russel[11] for 1,467 sows. In the "M" line the percentage of survival has been much lower, however. Temperament apparently has been a much bigger factor than vigor in affecting survival in this line. This is discussed later in this paper.

The records as tempered by interpretations of observations, indicate that loss of vigor has not been an important factor affecting death loss during early life.

Rate of growth.—Rate of growth is one of the best measures of vigor. The inbreds of the "N" line and the "M" line showed no difference from the non-inbreds for the first sixteen weeks. From then on, the non-inbreds gained more rapidly, reaching the 200-pound weight about three weeks earlier than the inbreds (Figure 11). This chart is based on weights taken every twenty-eight days for the past two years. The "L" line is not included because the numbers are too small to make a comparison of much value. It appears, however, that pigs of this line react



REPRESENTATIVE PIGS OF THREE INBRED LINES AND OF A CROSS BETWEEN TWO OF THEM

Figure 12

The symbol *I* indicates the number of generations of close inbreeding in the immediate ancestry of the individuals in question. Thus on "I_8" animal is the product of six generations of brother-sister matings. "Lodi" is an ancestor of all present "L" line stock. The I_5 and I_8 "M" line individuals are excellent pigs. Note the heavy jowl typical of the "N" line. The crossbred "N" × "M" pigs showed great uniformity and excellent conformation. Some of the inbred pigs showed nearly as rapid gain in weight as the crossbreds. The five crossbred pigs shown at the lower right had at an age of 32 weeks (when the photograph was taken), weights of 264, 266, 242, 247, and 284 lbs. Control non-inbreds had an average weight at 32 weeks of 220 lbs.

very differently; they are heavier at birth but grow much more slowly than the other inbred or outbred pigs.

There has been more variation in growth rate among the inbreds than among the non-inbreds. Some of the inbreds have gained as rapidly as the non-inbreds; but a number of slow growing pigs has pulled down the average.

The difficulty of controlling an experiment of this kind is always a complicating factor in properly interpreting results. The non-inbreds have in general been farrowed in March or early April, whereas the difficulty of making matings has spread the time of farrowing for the inbreds from March to May. Late pigs usually are at a disadvantage.

Economy of gains.—Unfortunately it has been impossible to obtain as much data regarding cost of gains as would have been desirable. A few litters, however, have been entered in the National Swine Record of Performance work at the Minnesota Station. The data in Table IV (from Ferrin, Anderson, and Johnson [4, 5]) show that the inbred litters entered made a poorer record than the average of other pigs entered by breeders throughout the state. That is not surprising. The I_3 litter of the "M" line, however, made more efficient gains than the average of other pigs entered. It is apparent that loss of vigor, as judged by economy of gains, has been rather slight.

Carcass value.—Pigs entered in Record of Performance are carried through a slaughter test. These data are included in Tables IV and V. In the margin between cost of gains and carcass value per 100 pounds, the inbreds show more favorably by contrast with the other pigs entered than in feed per 100 pounds gain. The reason for the difference is that the inbreds were of a somewhat more compact type; hence their dressing percentages were relatively high.

The carcass grades for the inbreds are presented in Table V. The data on carcass grades for the entire group have not been made available. Inspection of the data reveals, however, that the inbreds' carcasses graded considerably better than the poorest entered but not as high as the best. The average for the inbreds is probably slightly higher than that of the other pigs entered.

Conformation.—No marked change in conformation has accompanied the progress of inbreeding. Most visitors have been unable to distinguish between the inbreds and the non-inbreds of any age. No measurements were taken of the original stock, but the opinion of those who have followed this experiment is that the existing lines conform closely to the types that were used at the outset. The best type stock is to be found in the "M" line; most individuals of this line would pass as acceptable breeding stock. One branch of the "N" line has an unusually heavy jowl and a very characteristic snub nose much like a Berkshire's. The conformations of these hogs is revealed to better advantage by the accompanying illustrations than by descriptions (Figure 12).

Color.—The only unusual colors brought to light were in the "L" line. In the I_4 generation, a substrain for white spots and another substrain for yellow spots were produced. The white spotted pigs have been mistaken for Spotted Poland-China. The yellow spotted pigs are pink when born and gradually change to black, spotted with yellow and white. When the individuals reach about 250 pounds in weight most of the yellow color has changed to white. These hogs have also been mistaken for Spotted Poland-Chinas. It is odd, although it may have no significance, but none of these hogs have mated until the yellow color disappeared.

In the fifth generation of this line, a litter was born without the yellow color, but with considerably more white spotting than is common in Poland-China hogs. Representatives of this litter and the "yellow" strain are on

hand. Both strains will be perpetuated for future genetic studies.

Temperament.—Some rather unusual temperamental traits have been brought to light by the inbreeding. It has been impossible to attempt a genetic analysis of any of these traits; yet the evidence is entirely in keeping with the findings of Sadovnikova-Koltzova,[12] i. e., that temperament is inherited.

The "N" line shows some of the characters one would expect in the wild ancestors of modern swine. At birth, little pigs from this line are hard to catch, and when cornered they fight viciously. Regardless of the attempts made to tame the individuals of this line, the sows are savage at the time of parturition. Any unusual happening will set them raging. The first seventh generation litter of seven pigs belonging to this line did well for the first two days. Then the sow became excited over some trivial happening. She rooted the pigs into a corner, piled straw over them and then stood on the straw to defend her family. Every pig was trampled to death during the next six hours. The same sow farrowed a fall litter in an individual house in the pasture. No one went near her for a week, and she raised every pig.

Just the opposite type of disposition has come out of the "M" line. The individuals are easily handled; they are always friendly, and at farrowing time a child is safe playing with the pigs. This also has its disadvantages; excessive losses of young pigs have been experienced because of the extreme indifference of the old sows to the squeals of their young when stepped or lain on. This tendency has been especially noticeable in some litters. One very good-natured sow killed eighteen pigs in this way.

In this work it has been necessary to select for disposition. Fortunately some segregation has occurred and at present, two strains of each line are being carried. One "M" strain has good sized litters but does not raise many pigs because of this unusually docile temperament. One of the "N" substrains does not farrow many pigs, and in addition, the sows are so difficult to handle that the pigs are often killed.

The above extremes are being discarded in favor of strains which have the ability to farrow and raise normal sized litters, and at this time it appears that strains have been developed within both the "M" and "N" lines which can be perpetuated successfully.

Anomalies. — Surprisingly few but some very interesting anomalies have been brought to light. These few have affected the reproductive organs and especially their functioning. Not a single hernia has been produced in all the generations. Only two cryptorchids have been produced; one was an I_5 of the "M" line. He refused to mate with any sow. Dissection revealed one very small non-functional testis located well up the inguinal canal. The other testis was normal in size and shape. It had descended the inguinal canal, but the scrotum was so small that the testis was held very close to the body. This testis was not functioning normally, however; spermatogenesis was not carried to the full spermatozoa stage and the spermatogenic tubules were still partially closed. Histological sections of the seminal vesicles, prostate and bulbo-urethral glands revealed them as normal. It is interesting that the sire of this pig at two years old had a left testis which weighed 474 gms. while the right one weighed only 250 gms.

Louis and Louise, I_3 pigs of the "L" line, were an interesting pair. Both pigs were unusually difficult to work with; they both learned with great difficulty. Louis appeared to possess perfectly normal psychological sexual reactions but seemed physically unable to function normally. Eventually one testis and epididymis was removed. Spermatozoa removed from the epididymis appeared perfectly normal and in a normal saline solution remained motile for a long time. Louise was in heat at the time, she was inseminated artificially, but conception did not result. Louis was destroyed later; his reproductive or-

gans were dissected and histological studies made but no anomaly was uncovered. Louise was bred to another inbred boar. Seven pigs were produced but only two were raised.

Another I_3 pair, LeRoy and Leone, of the "L" line were very interesting. Leone failed to show any evidence of heat. Yohimbin was finally resorted to; she was given this drug regularly. The author is not certain that the drug had any effect, but eventually a mating was made and conception resulted. She was due to farrow August 11, 1929, and showed full evidence of pregnancy. On August 15 she passed an afterbirth. From that date on she failed gradually and died September 9. The post mortem examination revealed remnants of several dead pigs. Her reproductive organs were in very bad condition; the walls of the uterus had grown together and to the large bowel. It is unlikely that her organs were in that condition originally, but they must have been very abnormal.

Marshall and Marian, I_2 of the "M" line, present other anomalies. Early in the winter, Marian showed oestrum regularly, but Marshall could not be induced to mate. It appeared that the muscles of his back were defective. Late in February he mated with several Duroc Jersey sows. Semen was gathered; it contained a few sperms, but none was motile. Later, cod liver oil and a special mixture of minerals were added to his ration. He appeared to gain strength on this ration and began showing much more sexual interest. Marian, however, no longer showed oestrum. Fresh pituitary glands were grafted under her skin. She responded by coming in heat. She was not bred, however, but destroyed and her organs dissected. Her ovaries were covered with large cysts. Below is given a description of her organs by Dr. W. L. Boyd of the Division of Veterinary Medicine:

> Both ovaries were enlarged several times and extensively cystic. The right ovary weighed 185 grams; the left ovary weighed 109 grams. There was very little normal ovarian tissue. The uterus was of a milky white appearance, flaccid and showed little evidence of muscle tissue. When palpated, we found small shotlike collections that were quite firm. Upon incising the uterus we found a very imperfect canal, and the shotlike structures were comprised of a sticky, gumlike exudate, brown in color and free from calcarious material. The organs were photographed, and one of the ovaries preserved, the other being cultured, and guinea pigs were inoculated with the contents. Sections were taken from: uterus, ovaries, cervix, and oviduct. The oviducts were the only tissues that appeared to be normal. The entire structure resembled very closely an embryological defect.

Pedigrees and coefficients of inbreeding.—Extended pedigrees of these hogs are interesting but occupy too much space to be included. An abbreviated form has been developed giving the desired information regarding representative individuals of each line (Table VI). In an extended pedigree of Navon, an I_8 of the "N" line, the names of The Demo and Minnesota Girl 2nd

Table I. Size of litters.

Line Studied	Gen. Inbred	No. Pigs Born Per Litter												Average
		1	2	3	4	5	6	7	8	9	10	11	12	13	
Non inbred	0				1	1			2	1	4		3		9.2
N line	1							1			1		1		9.7
	2	1					1				1				8.7
	3		1				1				1		1		7.3
	4		1				1		1		1		2		8.3
	5				1	2	1	2	1						8.9
	6					1	1	1		1			1		7.6
	7				2	1		1		1					8.0
															7.1
N line	1									1			1		10.5
	2	1							1	1	2			1	8.5
	3					1	1	2		1					6.8
	4					1	2			1	2	1			8.1
	5	1	1		1	1	1	1	2		1				8.7
	6								2	1					8.3
															7.5
L line	1								1		1				9.0
	2						2	1		1					7.0
	3			2		1	2	1							6.0
	4			1	1				1	2					7.0
	5					2				1					6.0
															6.5
Three inbred lines	1							1	1		2		2		9.6
	2	2					2	1	1	2	2			2	7.9
	3		1	2		2	4	2		1	1		1		8.3
	4		1	1	1	1	2		2	4	2	1	2		7.8
	5	1	1		2	7	2	2	2	1	1				8.0
	6					1	1	1	1	2			1		8.0
	7				2	1		1		1					8.0
															7.1

would appear 256 times each. The average percentage of homozygosis in the advanced generations of each the "L," "M," and "N" lines would be approximately 83, 87, and 92, respectively. It is very possible that selection has retarded the approach to homozygosity. Both the natural and intentional selection has been for the most vigorous individuals; these individuals may have been the most heterozygous of their respective generations.

Breeding tests.—As yet, it has been impossible to carry out as extensive breeding tests as would be desirable, however, the two tests described below have been made.

In the fall of 1931 three outbred sows were bred to an I_5 "N" line boar. Three other sows, each of which was a litter mate to one of the above sows, were bred to the regular herd boar at the Central Station. The two groups of pigs resulting were given similar treatment. The pigs by the inbred boar made 0.16 pounds greater daily gains than the check lot and made their

Table II. Birth weight of pigs.

Line	Generations inbred	No. of litters	No. of pigs	Average birth weight in pounds	Range in birth weight
Non-inbred	0	7	61	2.7	1.1 - 4.0
"N"	5	8	49	2.46	1.2 - 3.2
"M"	6	8	39	2.36	1.9 - 2.9
"L"	7	2	11	2.45	1.7 - 2.8
"N"	5	9	81	2.72	1.4 - 4.0
"M"	6	3	17	2.94	2.3 - 3.3
"L"	8	4	28	3.0	1.2 - 3.9

Table III. Survival of pigs born.

	Pigs born	Born dead	Died or killed	Raised	Per cent raised
Non-inbred	97	5	17	75	77
"N" line I_5 and I_5	79	3	19	59	75
"M" line I_5 and I_6	50	3	26	19	38
"L" line I_4 and I_5	66	4	18	44	67

Table IV. Record of performance data on inbred pigs.

Year	Breeding	Total feed per 100 lb. gain	Margin between cost of gains and carcass value per 100 lb.
1930	I_5 inbreds	406.94	$ 3.49
1930	Ave. of 11 other groups entered	362.78	3.38
1931	I_5 inbreds ("N" line)	344.22	3.49
1932	I_4 inbreds ("L" line)	323.79	3.25
1931	I_4 inbreds ("N" line)	377.14	3.11
1931	Ave. inbreds	349.38	3.28
1931	Ave. of 11 other groups entered	350.69	3.52

Table V. Record of performance, carcass grades of the inbred pigs.

Breeding	Carcass grade	Ave. grade
I_5. "N" line	96.84 88.29 85.16	89.33
I_5. "M" line	87.64 90.17 87.72	88.52
I_4. "L" line	93.95 89.41 89.49	89.61
I_4. "N" line	93.00 82.64 85.07	86.90

Table VI. Abbreviated pedigrees of representative pairs of inbred pigs.

Line:	I_8	I_7	I_6	I_5	I_4	I_3	I_2	I_1	P_1	Foundation Animals
N	Mavon * 4/9/34	Mavor Mavoy 4/2/33 ** 4:4	Necord Neona 4/24/32 7:7 *** 2	Noah Norah 4/5/31 6:3 4	Neptune Nada 4/10/30 8:6 8	Norman Nelda 5/18/29 10:10 16	Nebo Nella 6/7/28 10:8 32	Nemesake Nina 4/23/27 7:6 64	Democrat Gertie 3/13/26 :11 128	The Demo Mimm.Girl 2d 256
M			Max Missy 8/21/33 8:5	Meder Meela 6/21/32 6:6	Maxim Maxie 4/26/31 6:5 2	Mallow Maxie 4/3/30 7:6 4	Mickey Marienne 5/3/29 9:8 8	Myron Myra 3/21/28 12:12 16	Mike Mina 5/20/26 8:7 32	Strongheart Rita 64
L				Loco Lolo 4/2/34 6:3	LaRazo LaLette 5/2/30 9:7	Lodi 5/5/28 6:4 Lulu 4/9/29 7:5 2	Lobo Lorna 3/23/27 4:4 4	Leo Lucy 5/2/25 6:6 8	Larry Leona 4/1/24 8:5 16	Giant Sensation Lola 32

* Date farrowed
** No. farrowed : No. raised
*** No. of times each appears in the pedigree

gains on slightly less feed, although it is likely that the difference is not significant. The pigs by the inbred boar were more uniform in type and in daily rate of gains.

In 1931 crosses were made between the three inbred lines, and four litters, 22 pigs of "N" × "L" and "N" × "M" breeding were grown in contrast with 16 non-inbred pigs. The average birth weights of the two lots were essentially the same; but the pigs from crossed inbred lines reached the 200-pound weight four weeks earlier than the non-inbred pigs. On the other hand, the advanced generations of inbred pigs require about 20 days longer than the non-inbred to reach 200 pounds in weight. Thus the "crossed" pigs reached a weight of 200 pounds nearly seven weeks earlier than the inbreds.

Summary

Registered Poland-China swine have been inbred by means of brother and sister matings for the past ten years. Seven different lines have been started. Three were lost in the first generation, and one was lost in the third generation. The remaining three lines have been carried successfully to the I_5, I_6, and I_8 generations. Two of the three lines, the "M" and "N" lines, are represented by two distinct strains which are in the I_6 and I_7 generations, respectively. Evidence indicates that these two main lines and their two sublines can be propagated indefinitely in this manner. The third line is still propagated with difficulty and the individuals are rather unsatisfactory.

Disposition apparently is inherited, and some undesirable factors have been segregated by the inbreeding process.

The number of anomalies produced has been surprisingly small. A few unusual ones have been segregated, but the most interesting and most perplexing segregations have been odd physiological and psychological sexual reactions. Two lines have been lost because of reluctance to mate and the difficulty has been encountered, but overcome, in the present inbred lines.

Two substrains splotched with yellow and white, respectively, were segregated in the "L" line.

The comparisons that have been made between non-inbreds with the advanced inbred lines, crosses of inbred lines, and the progeny by an inbred sire on non-inbred sows indicate that no vigor has been lost, but that segregation of vigor has occurred and furthermore that some lack of vigor has been eliminated.

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THE ROBERTSON STRAIN OF THE WASHINGTON NAVEL ORANGE

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THE attention of the writers was first called to the Robertson Strain of the Washington Navel Orange on May 29, 1933, by John E. Moore, an experienced citrus nurseryman and grower, who has charge of the orchard in which progeny trees of this strain are being grown. This orchard, which belongs to the estate of his father-in-law, Warren B. Robertson, is located in the Alvord section of the Riverside citrus district about midway between Arlington and Corona and just east of Magnolia Avenue on the slope of the western foothills of Arlington mountain.

The history of the limb sport from which this strain originated, as described by Mr. Moore follows*:

During the spring of 1925 Mr. Robertson's brother, Ray, was picking oranges in what is known as the old Benson grove of Washington Navels that is located on Walnut Road near Redlands, California, and near the top of one of the trees he found a limb bearing an unusually heavy quantity of fruit. He examined this fruit and noticed that it was somewhat different from the other fruit on the tree, having a larger size and smoother texture. He marked this limb and watched it for a period of two years and each year it bore a larger quantity of fruit of better commercial quality than that borne by the other limbs on this tree.

Warren B. Robertson visited the Benson grove during June, 1925, and his brother showed him the abnormal limb. He cut budwood from it, and top-worked one limb of a seven-year-old Mediterranean Sweet orange tree in his grove at Alvord with the buds.

A record for two years was kept of this budded limb during which time the fruit proved to have the same texture and characteristics as that on the original sport limb. At that time Mr. Robertson saw that it was earlier than the ordinary Washington Navels in his grove. He decided that he had found a new variety and gave it the name of "Robertson Cluster Navel" from the fact that it tends to bear its fruit in clusters. It now seems desirable to change this name to Robertson Navel.

*Personal letter, July 12, 1933.

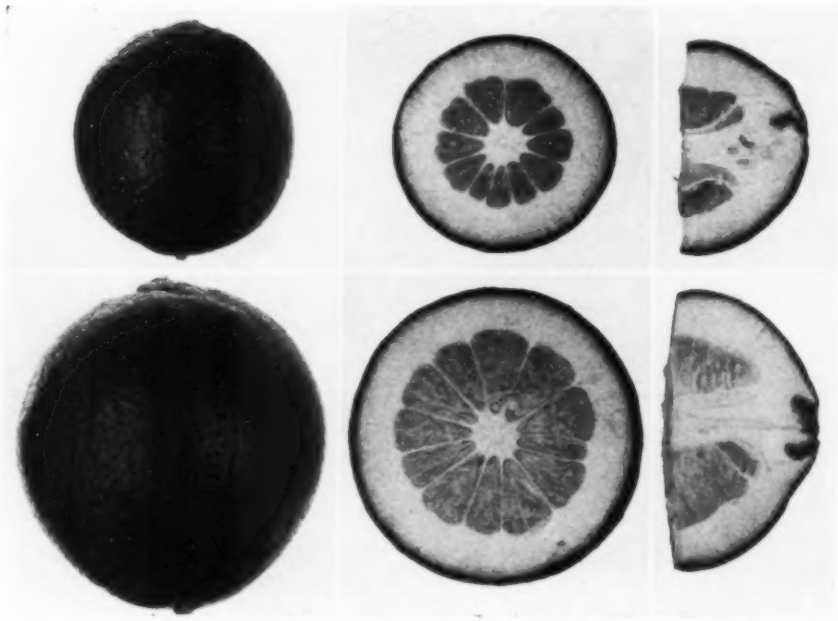
In June, 1927, he top-worked approximately ninety nine-year-old St. Michael orange trees in his Alvord orchard from this budded limb. The growth from the buds in these trees is now six years old and consistently produces fruit that is true to the characteristics of the original sport limb.

In 1930 he bought two-year-old sour-orange seedlings and planted them in an eleven-acre block in orchard form and budded them in June, 1931, from the top-worked trees. These orchard trees are now two years old and most of them have borne some fruit, all of which has also proved to be the same as that of the sport limb.

Some of the characteristics of the strain include: (1) The trees blossom practically at the same time as the ordinary Washington Navel trees but the young fruits of the strain grow much more rapidly than the normal and through so doing they become large enough to resist the usual heavy "June drop"; (2) Their best and most profitable characteristic is that during all the years that records have been kept the trees have never failed to bear abundant crops: (3) The fruit tends to grow in clusters, occasionally eight or nine or more oranges in one cluster: (4) The fruits of this strain mature two or three weeks earlier than those of the normal Washington Navel under comparable conditions as shown by their color and the soluble solids and acid tests of the juice.

Studies of the foliage and fruit on the budded limb in the Mediterranean Sweet orange tree, which was the first propagation of the limb sport, of the ninety trees top-worked from this budded limb in 1927, and of the young trees in the eleven-acre grove which is the third bud generation of the Robertson strain, were made on several occasions during the 1933 season by the writers, in comparison with the foliage and fruit characteristics of the normal Washington Navel orange trees in the same orchard.

Samples of typical fruits from trees of the two strains, obtained on May 29, 1933, showed that those of the Robertson strain were much larger than those of the normal strain. Later, on June 15, another examination of these



RAPID EARLY DEVELOPMENT OF ROBERTSON STRAIN FRUIT

Figure 13

In the upper row are shown fruit of normal Washington navel oranges and in the lower row fruit of Robertson strain oranges picked in the Alvord orchard on July 13, 1933. The Robertson strain fruits develop much more rapidly during their earlier stages of growth. As the season progresses this difference in size tends to disappear and at maturity the fruits are of about equal size. The Robertson strain fruits ripen as much as three weeks earlier than the Washington strain fruits.

fruits showed a decided difference in size, those of the Robertson strain being approximately four times larger than those of the normal strain. On July 13, typical fruits from the Robertson strain trees had an average circumference of 5.4 inches while the Washington Navel oranges averaged only 4.1 inches. (Figure 13). The difference in size of the fruits of the two strains on July 13 was not so great as it had been earlier. Subsequent visits to the orchard showed that the difference was becoming progressively less apparent and by November 1 very little difference in the size of the fruits of the two strains was to be observed. It seems probable from these observations, and those made by Mr. Moore during preceding years, that the main differences in the rate of growth of the fruits occurs during the early part of the season, and that during the later part of the season the fruits of the two strains tend to become of about equal size.

The tendency of the younger trees of the Robertson strain to produce rather compact groups of fruit or clusters, has been quite conspicuous in many of the trees. Often from five to nine oranges have been found to occur in a close group, while as many as twenty-five fruits were found in one large cluster on one of the two-year-old trees. In the larger clusters where individual fruits touch during their growth, discolored areas or blemishes are likely to develop on the rinds marring the ap-

FECUNDITY AND PRECOCITY OF ROBERTSON STRAIN

Figure 14

Typical Robertson navel orange tree which was top-worked on a nine-year-old St. Michael tree in June, 1927. This tree and the other trees in this block had to be propped in order to support the heavily laden limbs and avoid breakage. Photographed December 20, 1933.

A typical young Robertson strain tree in the Alvord orchard grown from a bud inserted in June, 1931, in a three-year-old sour-orange seedling, showing heavy crop borne in clusters and the compact and somewhat drooping habit of growth. Photographed December 8, 1933.

pearance of the fruits to some extent.

There are some indications that the development of fruit clusters tends to be less pronounced under certain growth conditions or with increasing age of the trees. The original eight-year-old top-worked limb in the Alvord grove did not develop any large clusters during the 1933 season and the six-year-old top-worked trees produced fewer and smaller clusters than was the case with the two-year-old trees.

The oranges of the Robertson strain mature somewhat earlier than comparable normal Washington Navel oranges as shown by their color and juice characteristics. The difference in time of maturity of the fruits of the two strains amounted to about three weeks during the present season and Mr. Moore reports that this relative condition of maturity has been consistently true throughout his experience with these strains. A juice test of comparable fruits of the two strains made on November 1, 1933, gave a soluble solids and acid ratio of 7.8 to 1 for the Robertson strain oranges, and 7.1 to 1 for the Washington strain oranges. A similar test on December 1, 1933, gave a ratio of 8.9 to 1 for the Robertson strain fruits and of 7.2 to 1 for the normal ones. On this later date the yellowish-orange color of the Robertson strain oranges was developed to a point where the fruits would easily have passed the California maturity color standards, while those of the normal strain were so green as to fall considerably below the standard requirements and were at least three

weeks later in this respect than the Robertson fruits. Systematic studies throughout the 1933 season strongly indicate that earliness of maturity is an inherent characteristic of the fruits of the Robertson strain.

While it was impossible to obtain comparable individual tree yield records in the Alvord orchard on account of the marked differences in the ages of the trees of the Robertson and those of the normal strain, estimates as to the relative quantity of production showed that the Robertson strain trees were much more productive than those of the normal one. This difference in quantity of production was doubtless largely due to the very rapid growth of the young fruits of the Robertson strain which gives them greater resistance to extreme climatic conditions during the late spring and early summer seasons at which time a heavy drop of very small Washington Navel oranges, the so-called June drop, usually occurs in that district. The larger young fruits of the Robertson strain are not as seriously affected by the adverse climatic conditions as the smaller fruits of the normal strain and fewer of them drop from the trees so that heavier crops are developed. From these observations and those of Mr. Moore during previous seasons, there seems to be no doubt but that the Robertson strain trees tend to produce larger quantities of fruit than comparable normal trees under the environmental conditions in the Alvord orchard.

One apparent characteristic of the Robertson strain fruits during the past season was the development of abnormally large navel openings with protruding navels in some of the fruits, particularly those borne by the younger trees having the most vigorous vegetative growth. In the older trees of this strain in which growth is less abundant and less vigorous there appeared to be only about the same number of fruits with abnormal navels as were found in comparable Washington strain trees.

The texture of the rinds of the Robertson strain fruits was somewhat smoother than that of the Washington strain oranges. The color of the rinds of mature fruits was about the same in both strains. The thickness of the rinds of the fruits of the two strains appeared the same. In color of flesh, amount of rag, tenderness, and amount and flavor of juice the Robertson strain fruits were quite similar to the Washington fruits.

The average size of oranges at the time of maturity in 1933 was about the same in the Robertson strain trees as that of comparable Washington strain fruits. In some trees the oranges were slightly smaller than those of the normal strain and this condition may have been due to the much heavier crops of fruit on some of the Robertson strain trees, or to environmental differences.

The habit of growth of the Robertson strain trees is more pendant or drooping than that of the Washington strain trees. This condition may be due in part to the weight of the heavy crops of fruit that tend to pull the branches downward during the fruiting season. Very little sucker or non-fruit-bearing growth has been found in any of these trees so that practically all of the branches were apparently pulled down by the weight of their fruits, thus giving them a drooping appearance. The leaves on the Robertson strain trees were quite similar in size, shape, and color to those of the Washington strain trees in the same orchard. The Robertson strain trees appeared to grow less vigorously and this is probably correlated in some degree with their relatively heavier production of fruit.

Several striking variations in quantity and commercial quality of fruit have been noticed in trees both in the young budded seedling orchard and in the older top-worked block. These variations indicate the possibility of the improvement of this strain through systematic bud selection practices.

The writers have not attempted to evaluate any possible commercial importance of the Robertson strain to the orange industry. Their observations have been confined solely to the progeny trees in the Alvord orchard and

to the study of the striking characteristics of their fruits and foliage during the 1933 season. That the characteristics of the parent bud sport have been transmitted through bud propagation has been proved by the progeny tests in this orchard but there has been no opportunity for a conclusive study of the value of the strain from the commercial standpoint.

Summary

The Robertson strain of the Washington Navel orange, originated from a limb sport, has been proved through progeny tests to transmit its characteristics in bud propagation. These characteristics are: rapid growth of the small fruits soon after blossoming, a tendency of the fruits to occur in clusters, heavy production, early maturity, very smooth texture of the rinds, the development of rather large navels in some of the fruits borne by the most vigorous growth of some of the younger trees, and the relatively short, pendant vegetative growth, giving the trees a somewhat dwarf or drooping appearance.

NEMATODES AND PLANT DISEASE

INFORMATION regarding plant parasitic nematodes is brought together in one publication for the first time.* The author begins his discussion by a chapter on general considerations, containing notes on general nemic structures, technique, measurements and systematics as applied to plant parasitic forms.

Following this introductory chapter, the various species are discussed, giving their scientific names, synonymy, history, morphology, life history, disease symptoms produced on the hosts, pathology, list of hosts (or references), geographical distribution (general), control and literature references. The arrangement employed is one from a plant pathological viewpoint.

This book, containing 306 pages, 136 illustrations and a fairly complete bibliography, presents the subject matter in a form which should be of assistance to the plant pathologist, the parasitologist, to all who have to do with the raising of plants, and to the zoologist. The chapter on biologic races is of special interest to the geneticist.

The author contends that certain nemas, for example *Anguillulina dipsaci*, may exhibit unspecialized polyphagous races, where a given nemic population may infest many hosts; more specialized races, which are able to infest fewer hosts; and highly specialized races which are able to infest only one or two hosts. He does not attempt to explain the cause of these races but intimates that the highly specialized ones have had a long history of parasitism in a particular host. These "biological races" and their behavior in selecting one or more hosts are not yet understood and little has been done to ascertain their evolution.

The material compiled here was widely scattered through various branches of scientific literature. Unfortunately this often becomes too manifest in the book, the presentation consisting too often of mere quotations. Perhaps this first attempt to assemble knowledge in this field will result in increased interest and activity in this important and neglected field.

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*GOODEY, T., *Plant Parasitic Nematodes and the Diseases They Cause*, E. P. Dutton and Co., 1933.

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